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Gillman et al.

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(54) **DEVICES AND METHODS FOR HIP REPLACEMENT**

(71) Applicants: **Michael Gillman**, Laguna Beach, CA (US); **Benjamin A. Gillman**, Laguna Beach, CA (US)

(72) Inventors: **Michael Gillman**, Laguna Beach, CA (US); **Benjamin A. Gillman**, Laguna Beach, CA (US)

(73) Assignee: **Bullseye Hip Replacement, LLC**, Las Vegas, NV (US)

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(51) **Int. Cl.**

A61B 17/17	(2006.01)
A61B 17/56	(2006.01)
G06T 7/00	(2006.01)
A61F 2/30	(2006.01)

(Continued)

(52) **U.S. Cl.**

CPC ***G06T 7/0012*** (2013.01); ***A61B 17/1746*** (2013.01); *A61B 19/50* (2013.01); ***A61F 2/30942*** (2013.01); ***A61F 2/34*** (2013.01); ***A61F 2/4609*** (2013.01); *A61B 2017/568* (2013.01); *A61B 2019/508* (2013.01); *A61F 2002/4627* (2013.01); *A61B 2019/502* (2013.01); *A61B 2019/505* (2013.01); *A61F 2002/4677* (2013.01); *A61F 2002/4681* (2013.01)

(58) **Field of Classification Search**

CPC A61B 17/1746; A61B 19/50; A61B 2017/568; A61F 2/30942

USPC 606/91, 96

See application file for complete search history.

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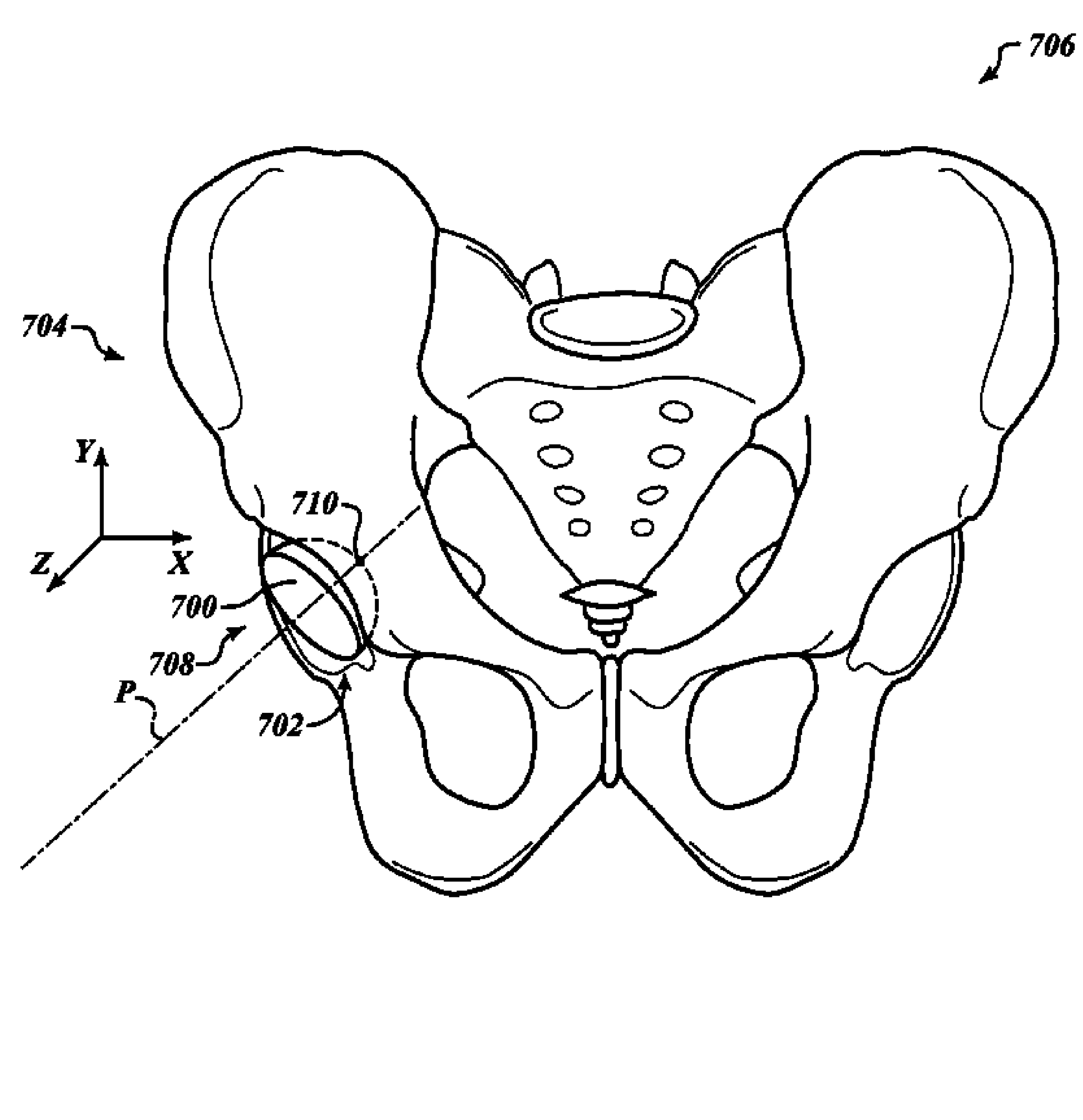
Primary Examiner — Andrew Yang

(74) *Attorney, Agent, or Firm* — Seed IP Law Group PLLC

(57) **ABSTRACT**

Devices and methods for use in hip replacement surgery can incorporate computer models of a patient's acetabulum and surrounding bone structure, a first patient-specific jig designed from the computer model and configured to correspond to a final installation position and orientation of a prosthetic him implant, a second patient-specific jig, also designed from the computer model, configured to refine the procedure, if necessary, following use of the first patient-specific jig, and/or a third patient specific jig, designed from the computer model, configured to refine the procedure, if necessary, following use of the first and second patient-specific jigs, allowing the surgeon to properly position and orient the hip prosthesis. Also shown and described are novel devices for implanting an acetabular cup.

21 Claims, 16 Drawing Sheets



(51) **Int. Cl.**

A61F 2/34	(2006.01)
A61F 2/46	(2006.01)
A61B 19/00	(2006.01)

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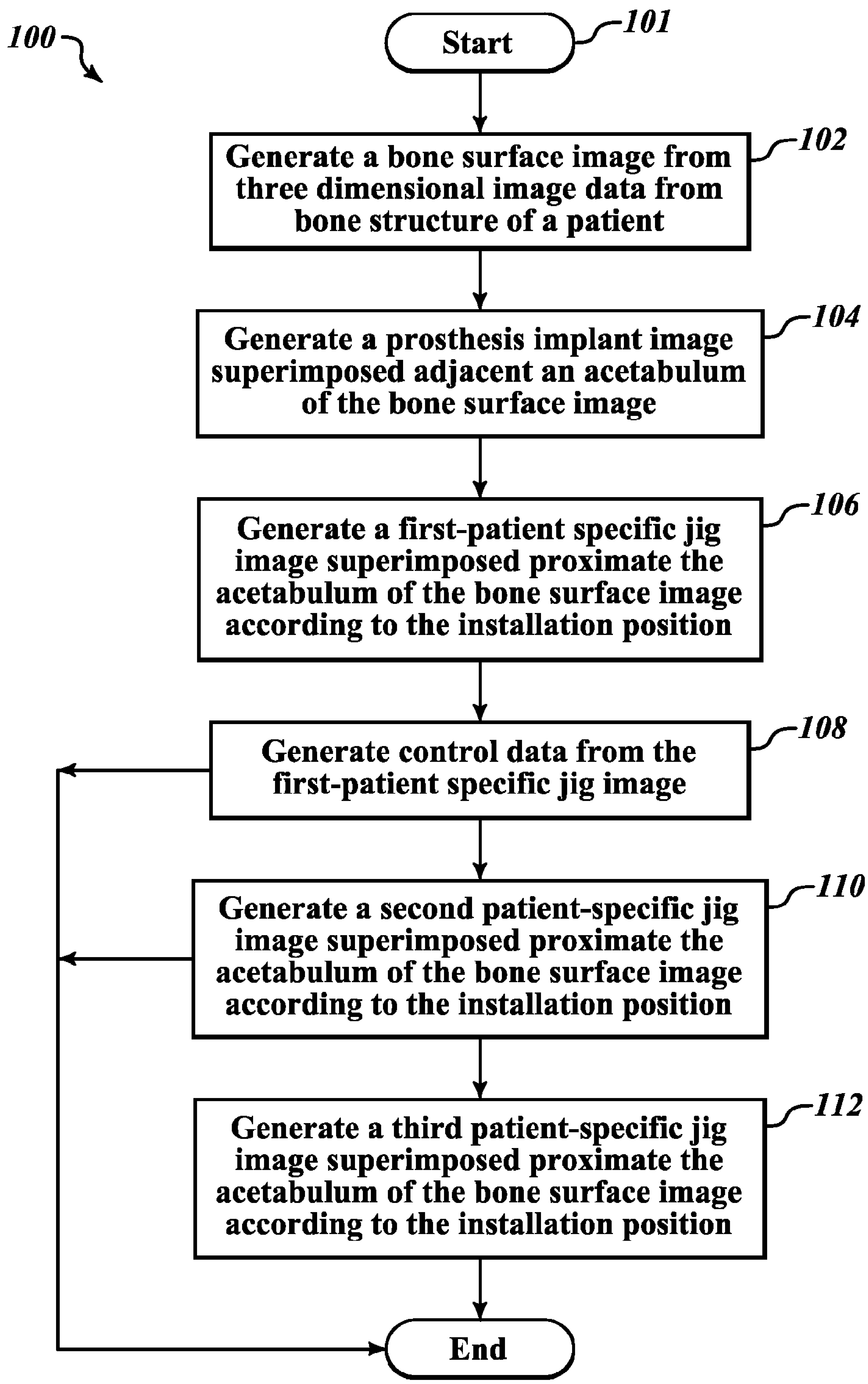
100
Start
101
Generate a bone surface image from three dimensional image data from bone structure of a patient
102
Generate a prosthesis implant image superimposed adjacent an acetabulum of the bone surface image
104
Generate a first-patient specific jig image superimposed proximate the acetabulum of the bone surface image according to the installation position
106
Generate control data from the first-patient specific jig image
108
Generate a second patient-specific jig image superimposed proximate the acetabulum of the bone surface image according to the installation position
110
Generate a third patient-specific jig image superimposed proximate the acetabulum of the bone surface image according to the installation position
112
End

FIG. 1

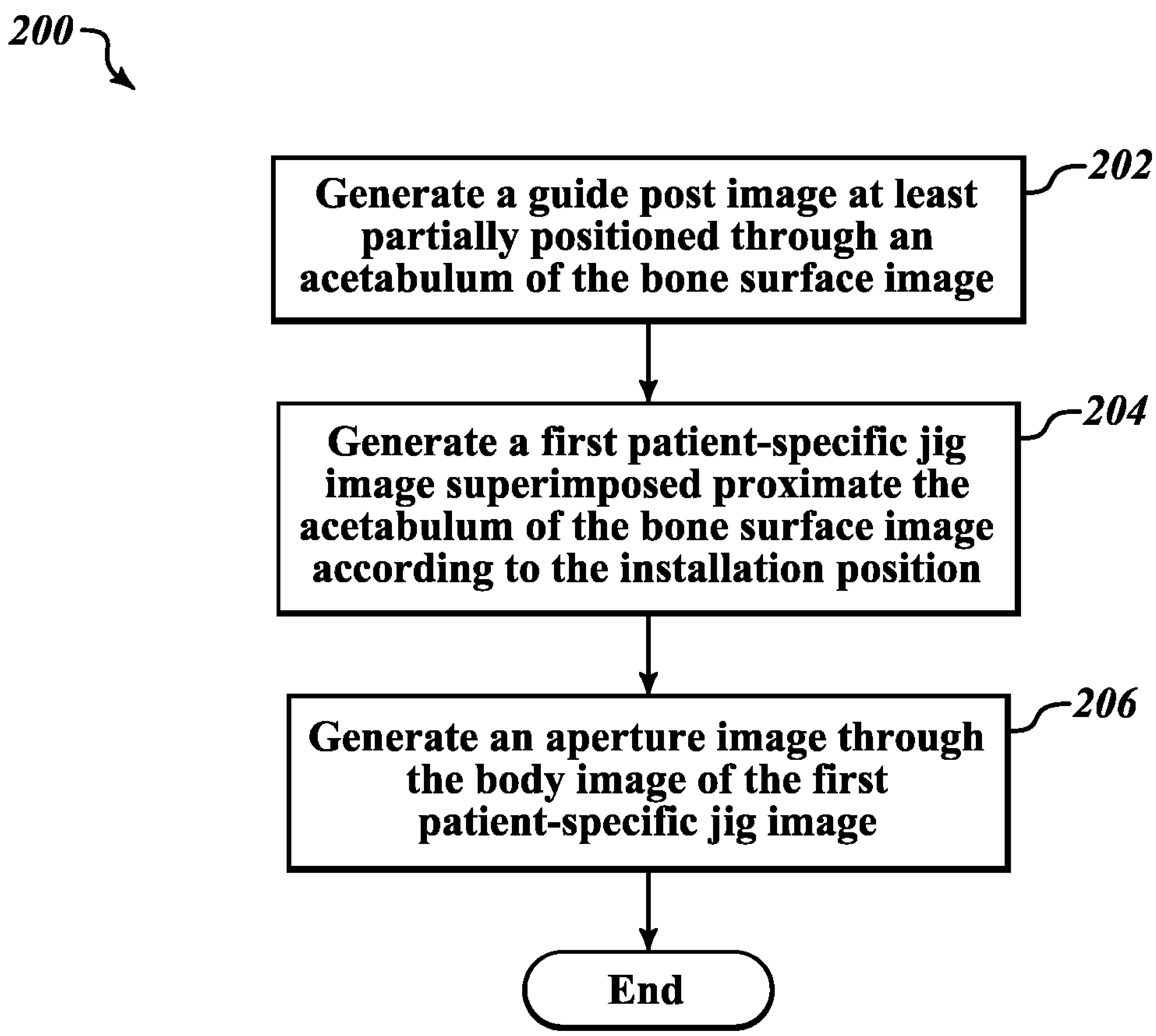
200
Generate a guide post image at least partially positioned through an acetabulum of the bone surface image
202
Generate a first patient-specific jig image superimposed proximate the acetabulum of the bone surface image according to the installation position
204
Generate an aperture image through the body image of the first patient-specific jig image
206
End

FIG.2

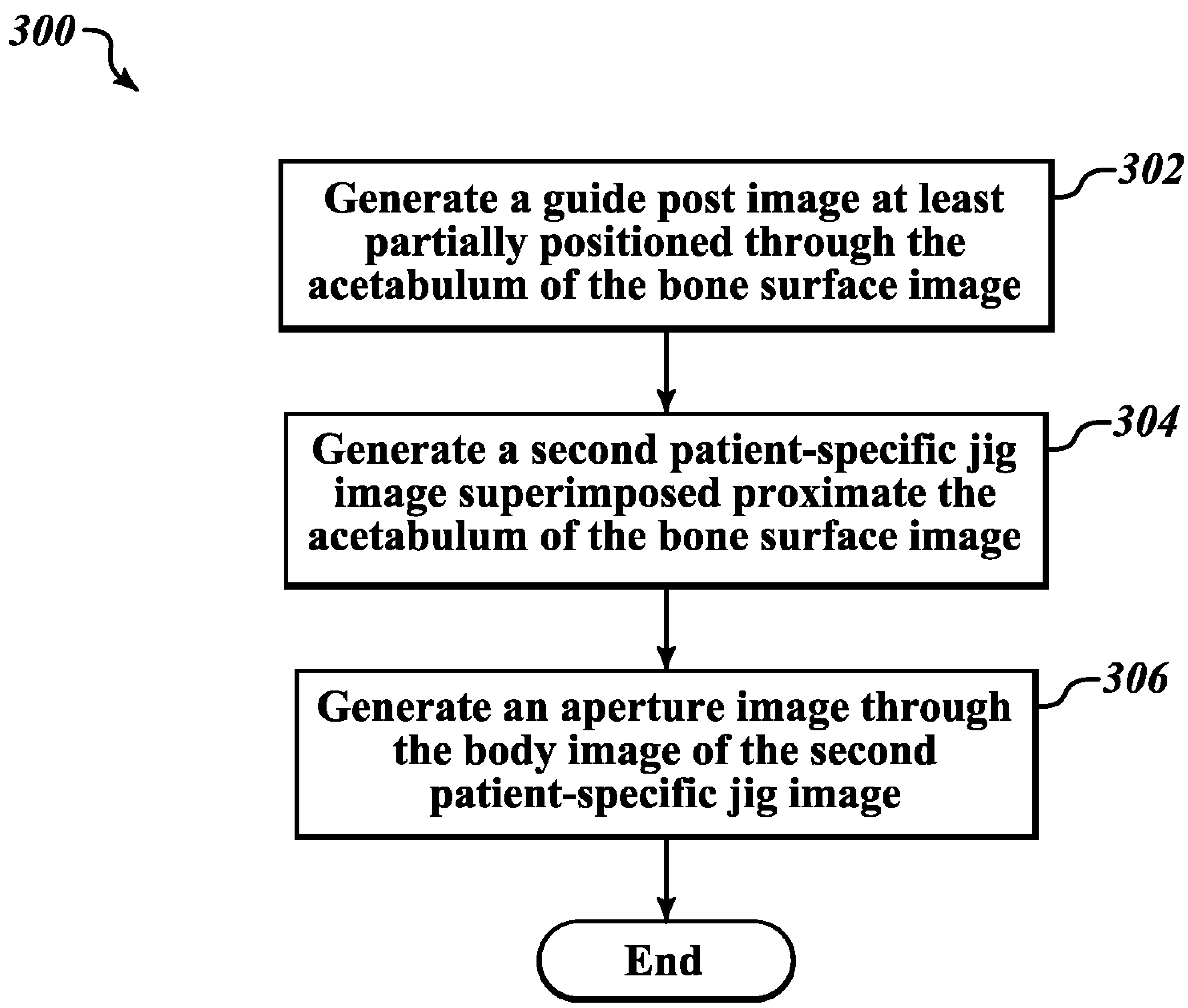
300
Generate a guide post image at least partially positioned through the acetabulum of the bone surface image
302
Generate a second patient-specific jig image superimposed proximate the acetabulum of the bone surface image
304
Generate an aperture image through the body image of the second patient-specific jig image
306
End

FIG. 3

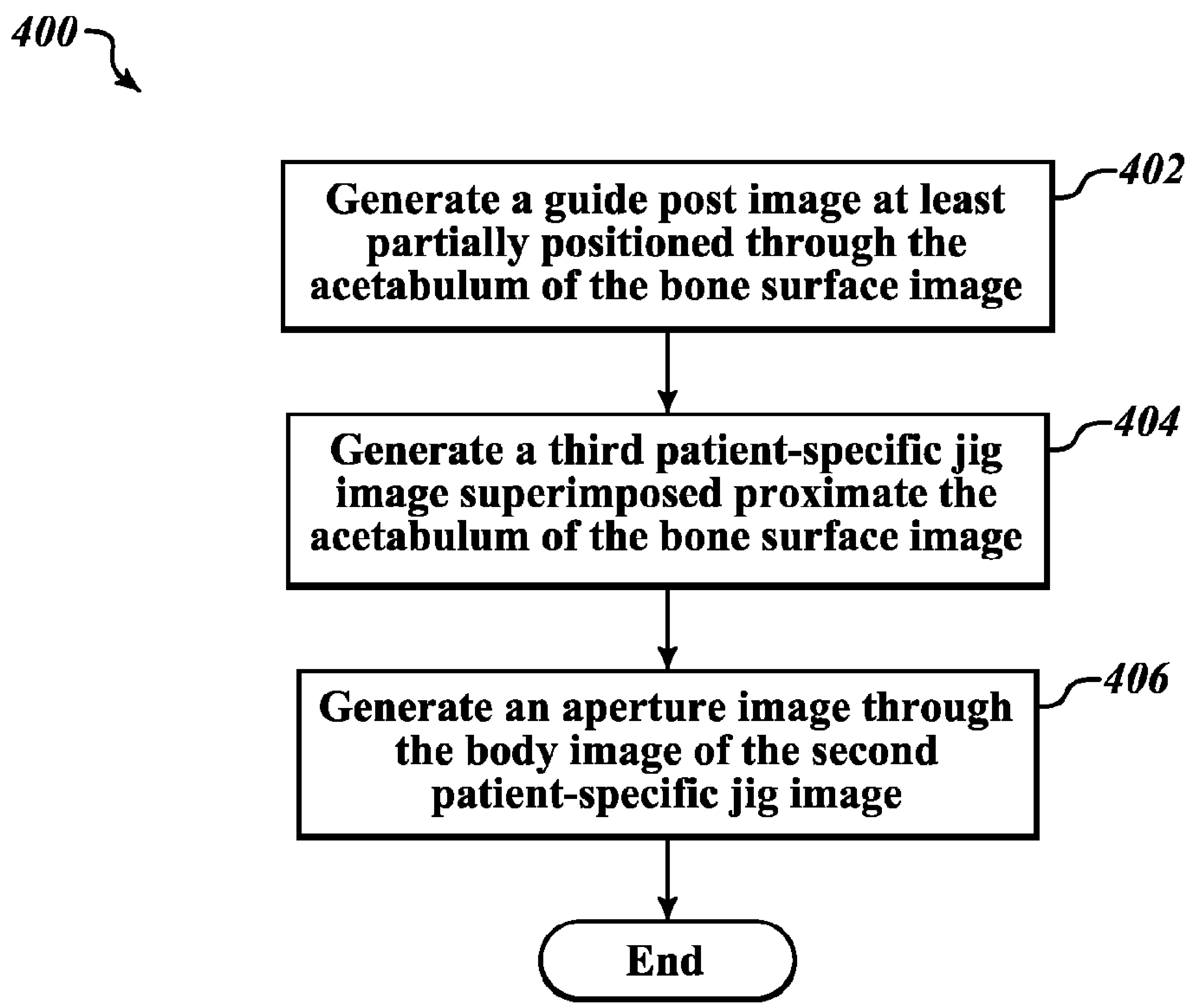
400
Generate a guide post image at least partially positioned through the acetabulum of the bone surface image
402
Generate a third patient-specific jig image superimposed proximate the acetabulum of the bone surface image
404
Generate an aperture image through the body image of the second patient-specific jig image
406
End

FIG.4

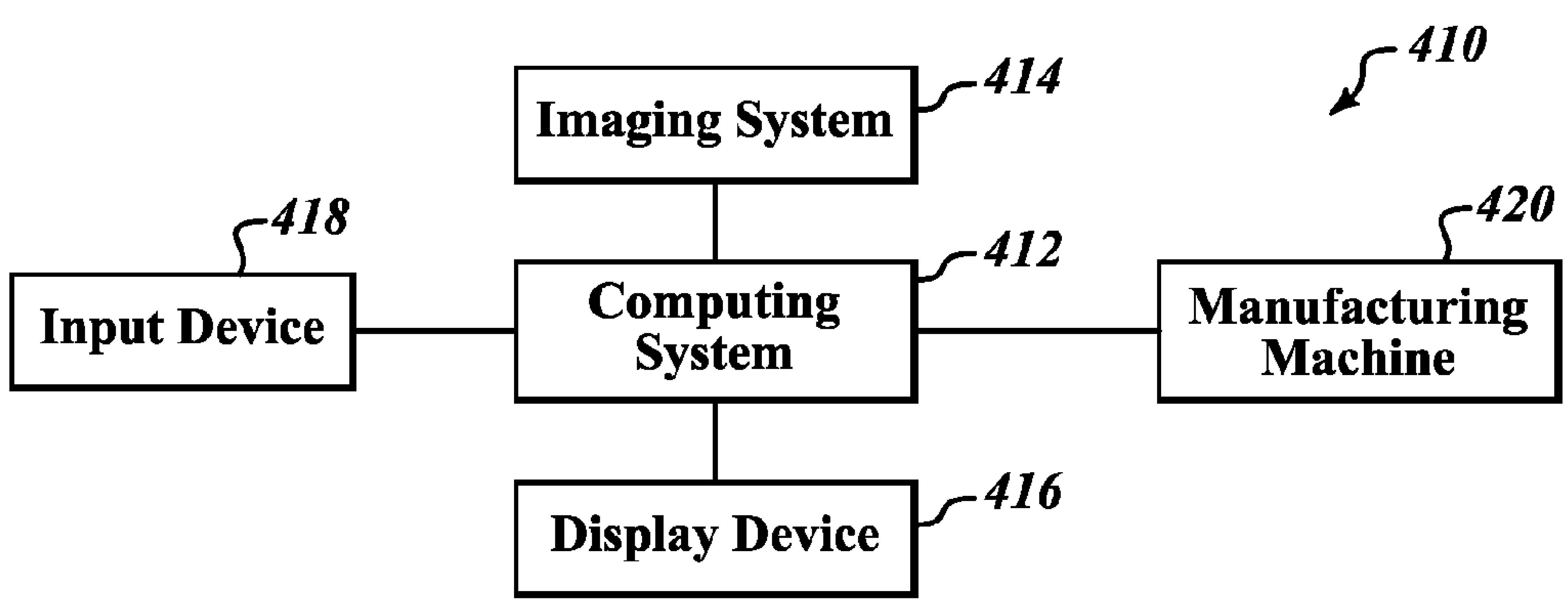
Imaging System
414
410
418
Input Device
Computing System
412
420
Manufacturing Machine
Display Device
416

FIG.4A

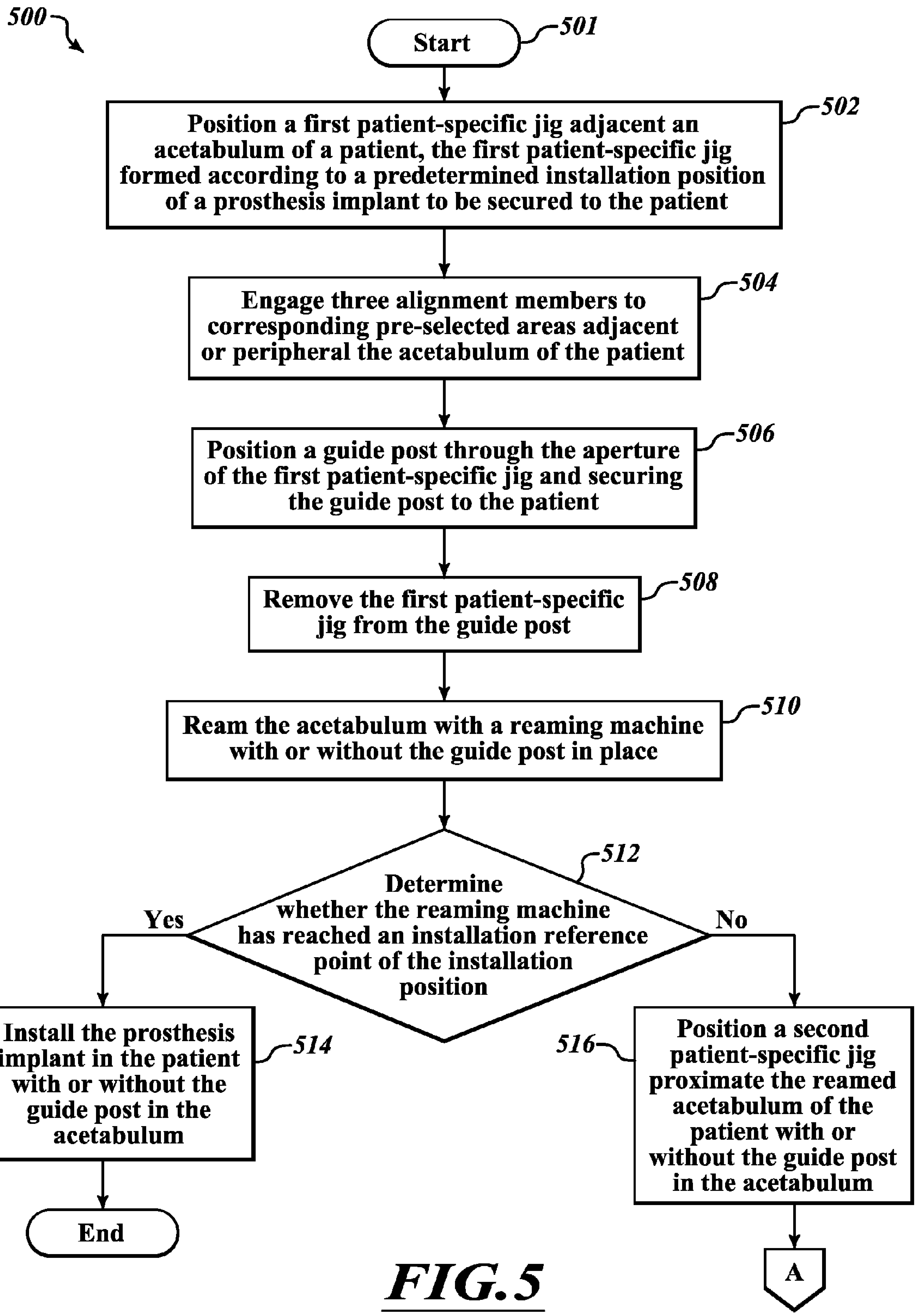
500
Start
501
Position a first patient-specific jig adjacent an acetabulum of a patient, the first patient-specific jig formed according to a predetermined installation position of a prosthesis implant to be secured to the patient
502
Engage three alignment members to corresponding pre-selected areas adjacent or peripheral the acetabulum of the patient
504
Position a guide post through the aperture of the first patient-specific jig and securing the guide post to the patient
506
Remove the first patient-specific jig from the guide post
508
Ream the acetabulum with a reaming machine with or without the guide post in place
510
Determine whether the reaming machine has reached an installation reference point of the installation position
512
Yes
No
Install the prosthesis implant in the patient with or without the guide post in the acetabulum
514
516
Position a second patient-specific jig proximate the reamed acetabulum of the patient with or without the guide post in the acetabulum
End
A

FIG. 5

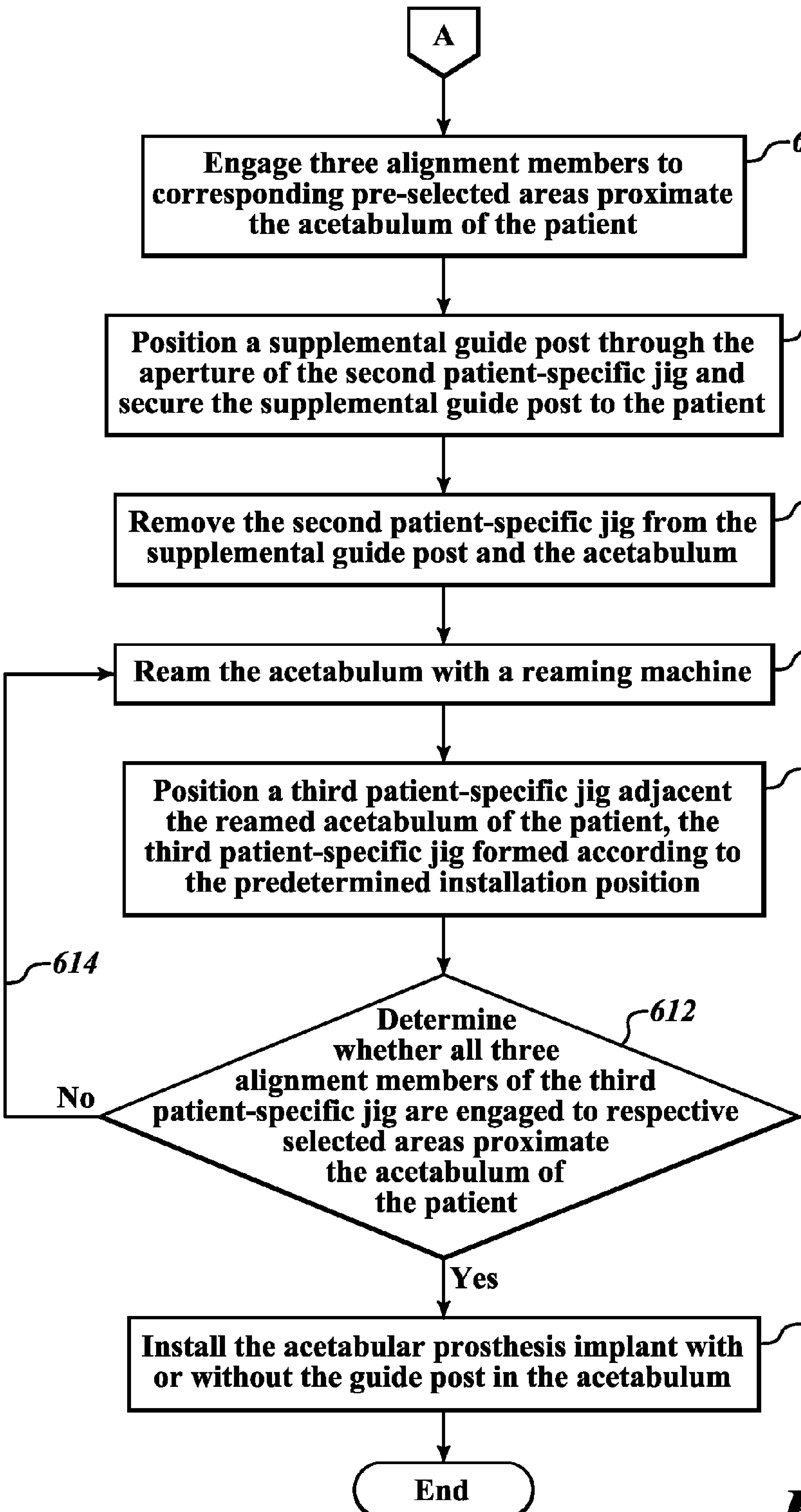
A
Engage three alignment members to corresponding pre-selected areas proximate the acetabulum of the patient
602
Position a supplemental guide post through the aperture of the second patient-specific jig and secure the supplemental guide post to the patient
604
Remove the second patient-specific jig from the supplemental guide post and the acetabulum
606
Ream the acetabulum with a reaming machine
608
Position a third patient-specific jig adjacent the reamed acetabulum of the patient, the third patient-specific jig formed according to the predetermined installation position
610
614
Determine whether all three alignment members of the third patient-specific jig are engaged to respective selected areas proximate the acetabulum of the patient
612
No
Yes
Install the acetabular prosthesis implant with or without the guide post in the acetabulum
616
End

FIG. 6

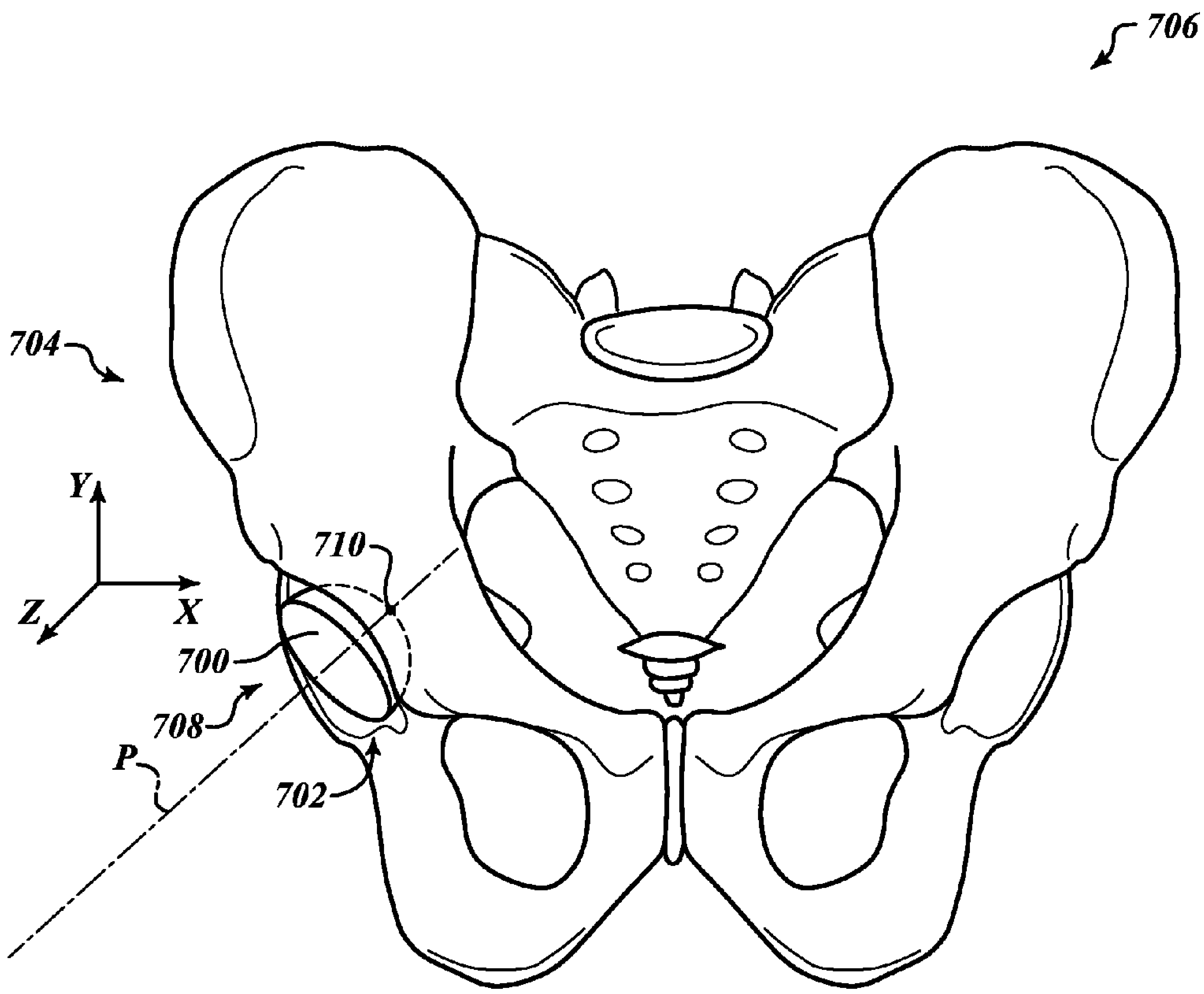

FIG. 7

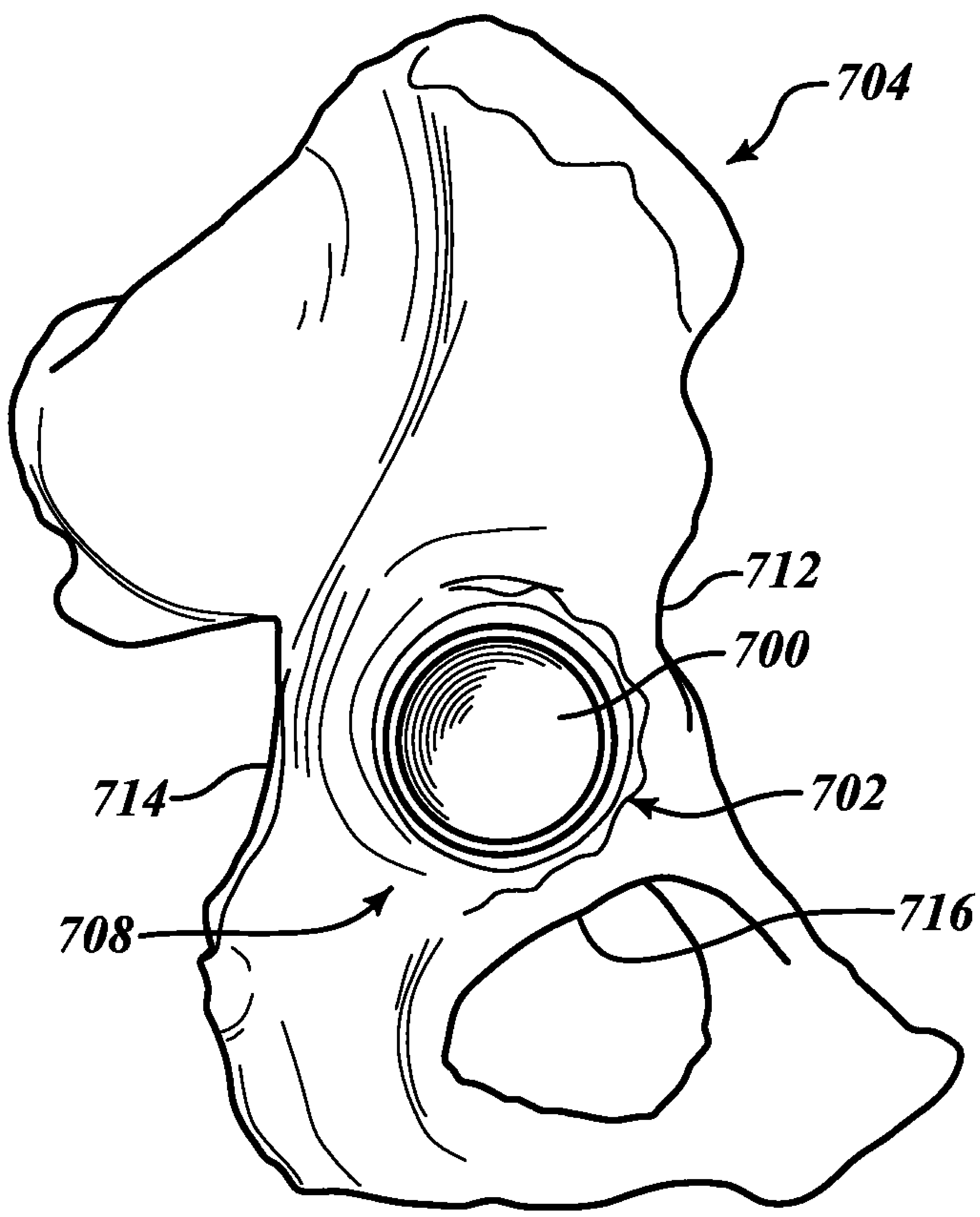

FIG.8

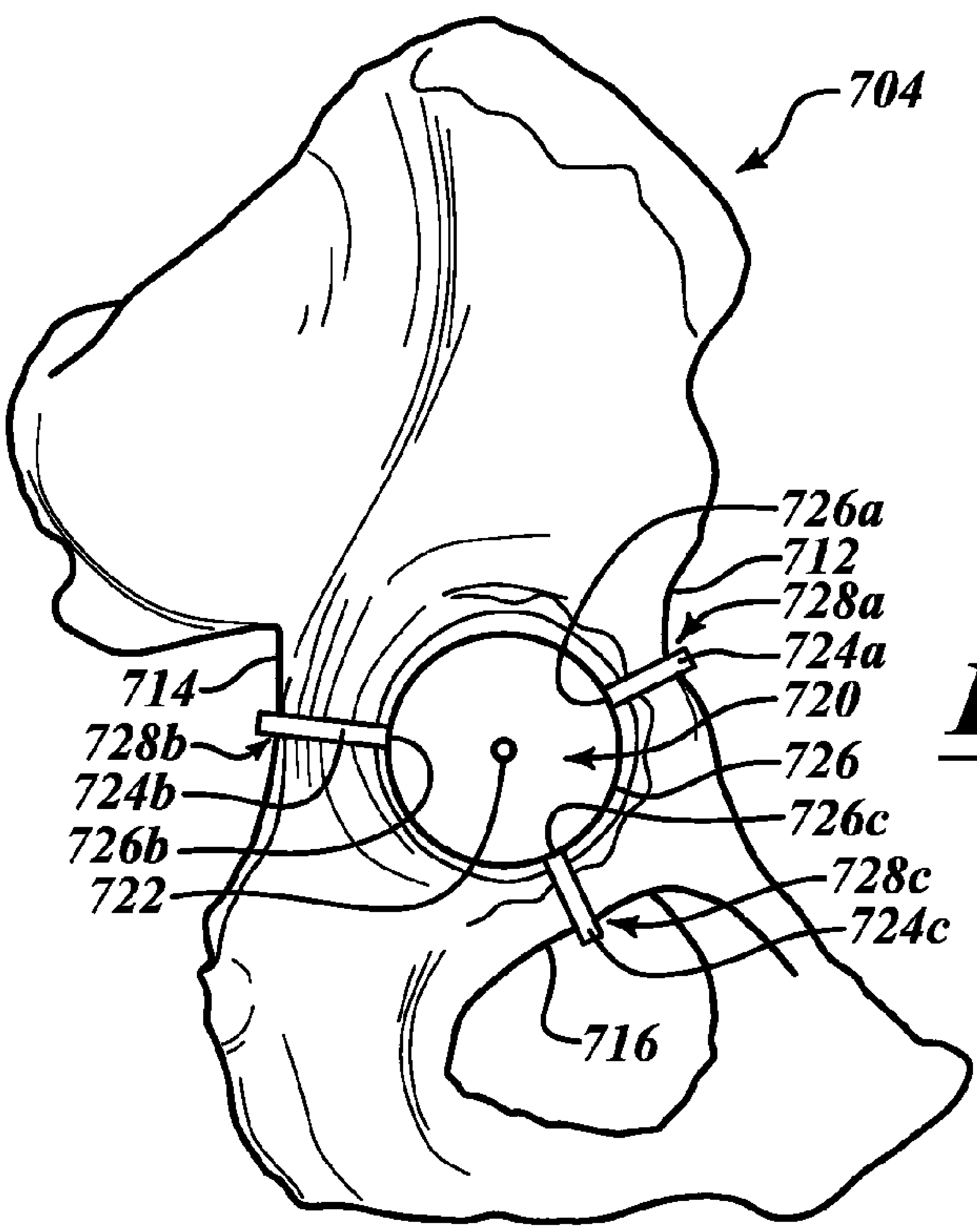
704
726a
712
728a
724a
720
726
726c
728c
724c
716
714
728b
724b
726b
722

FIG.9A

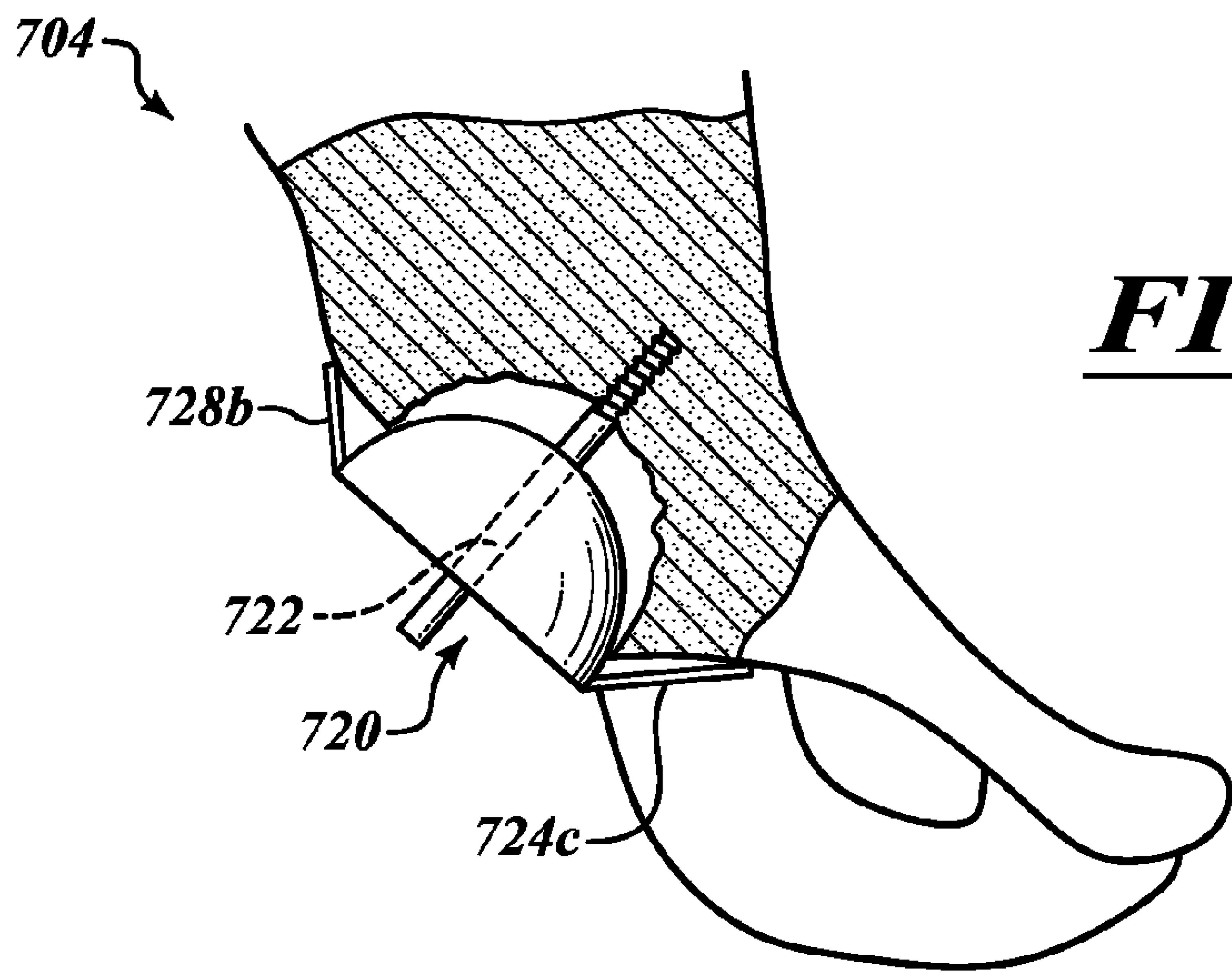
704
728b
722
720
724c

FIG.9B

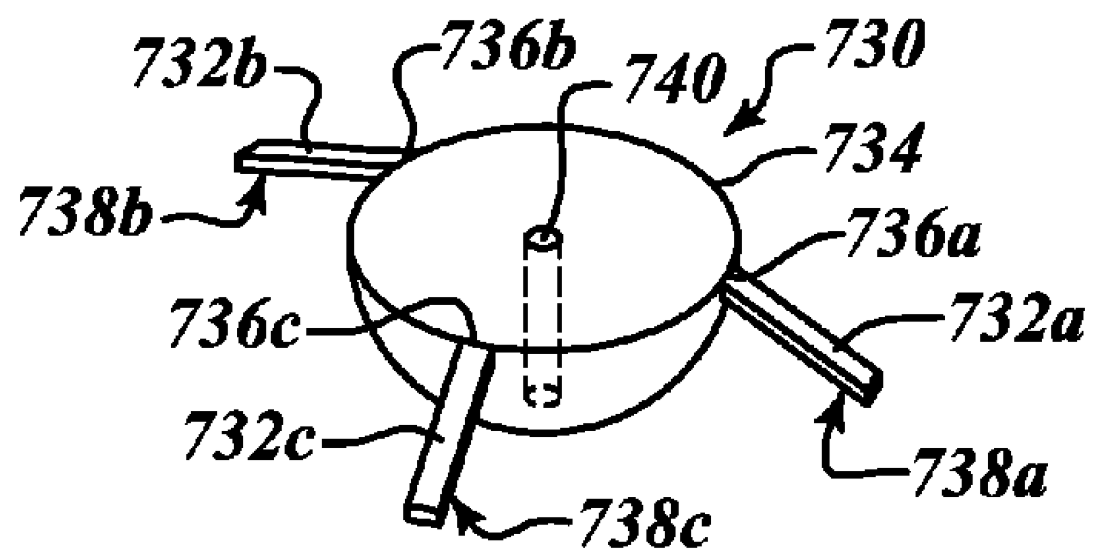

FIG.10A

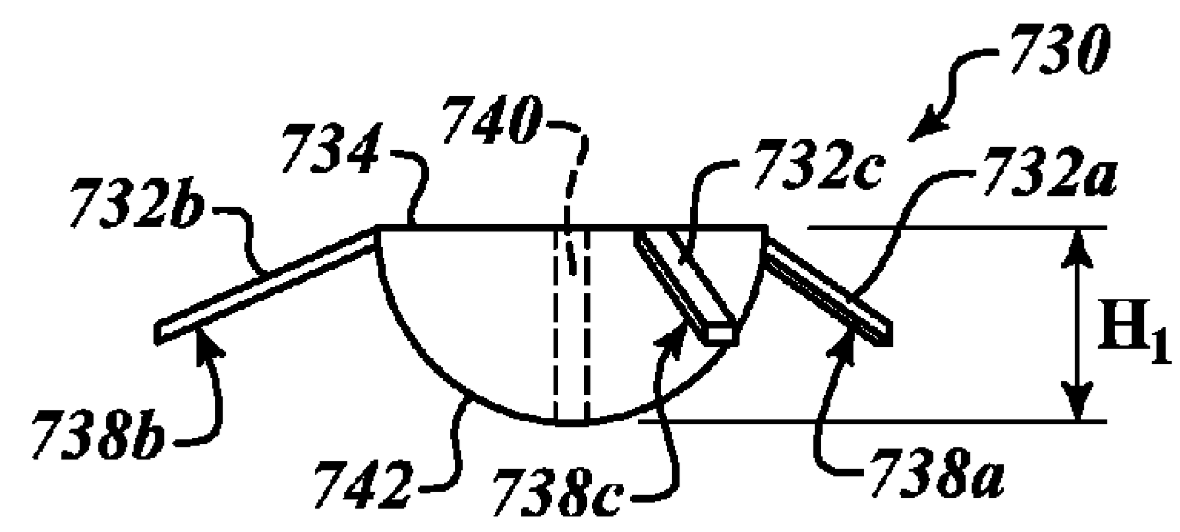

FIG. 10B

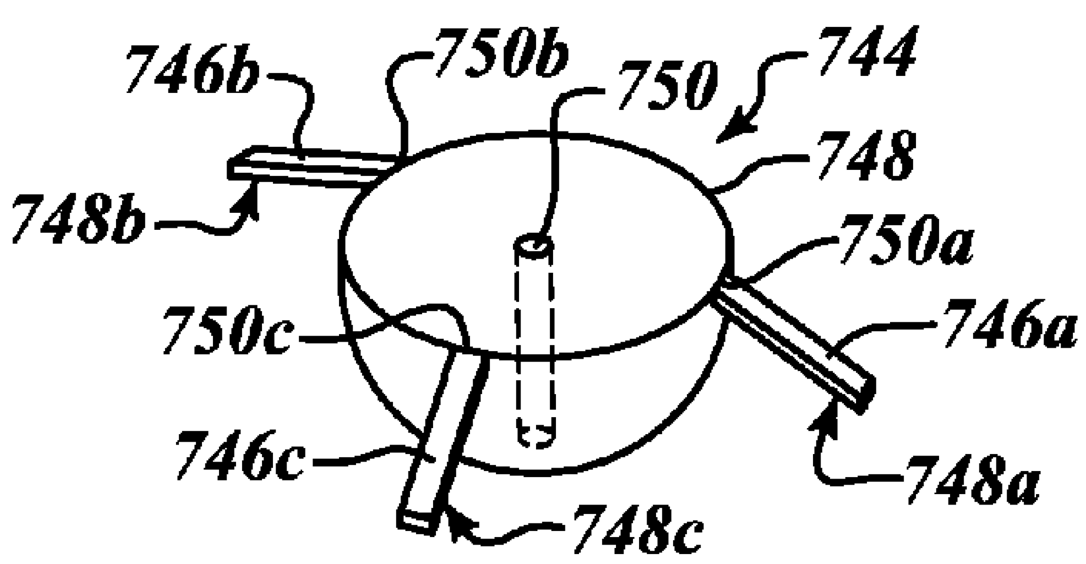

FIG.11A

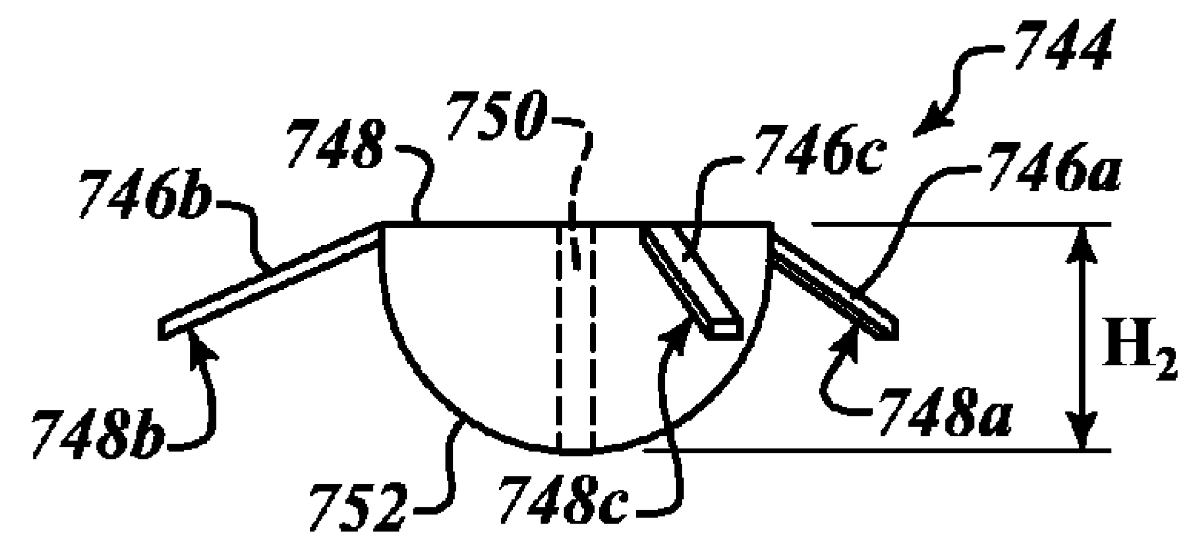

FIG. 11B

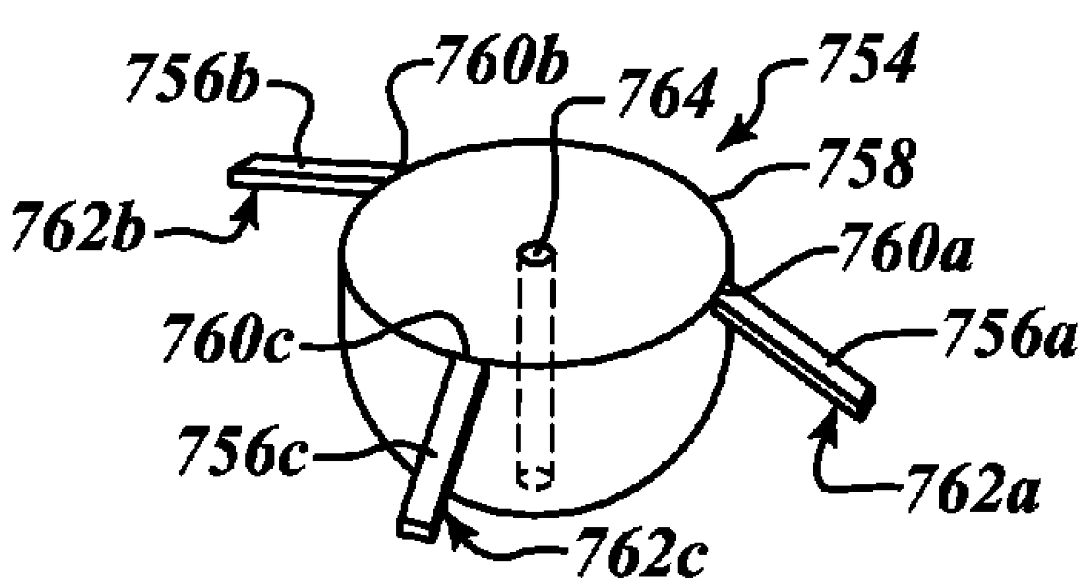

FIG.12A

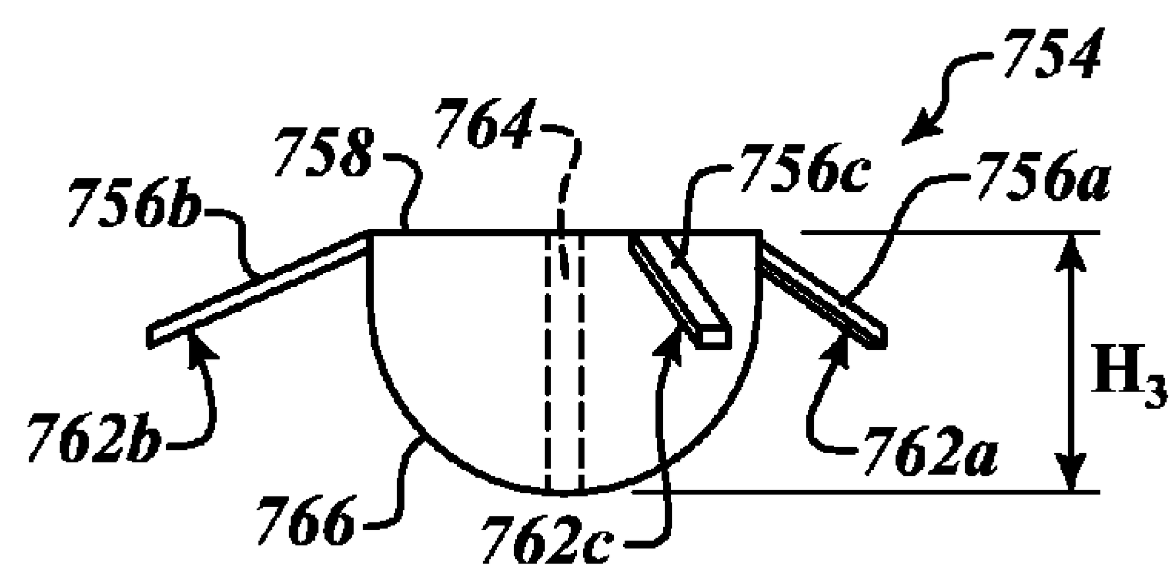

FIG. 12B

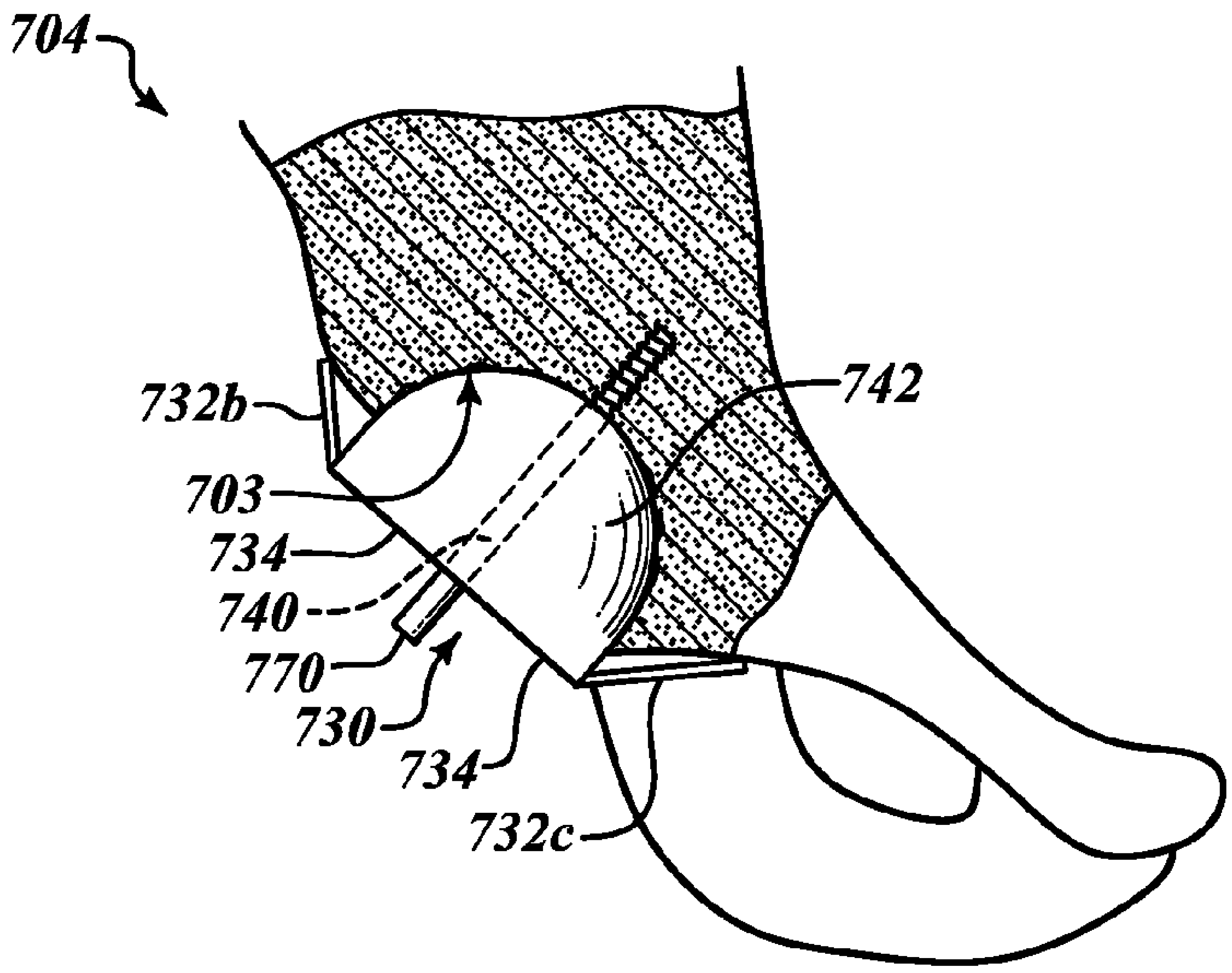

FIG.13A

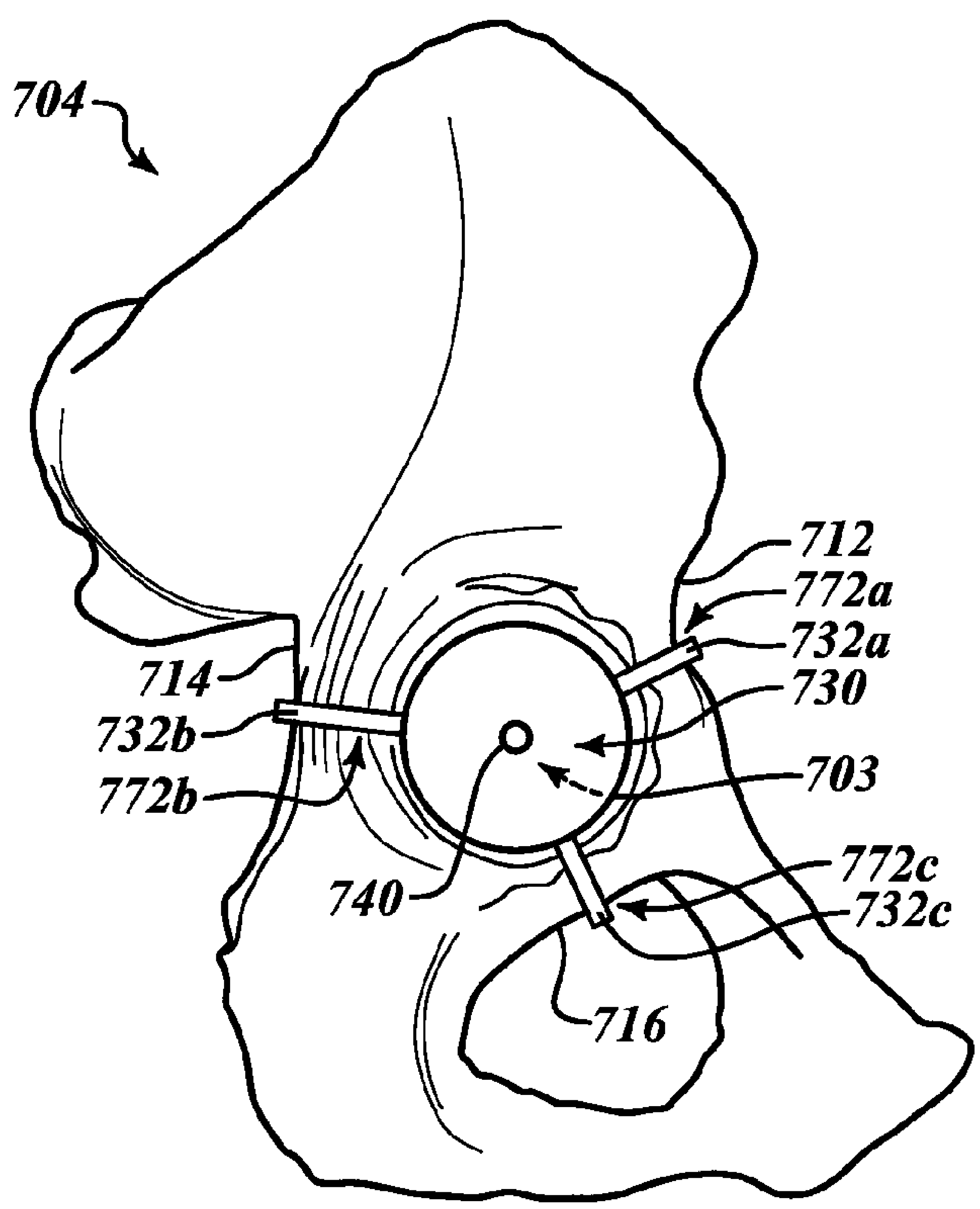

FIG.13B

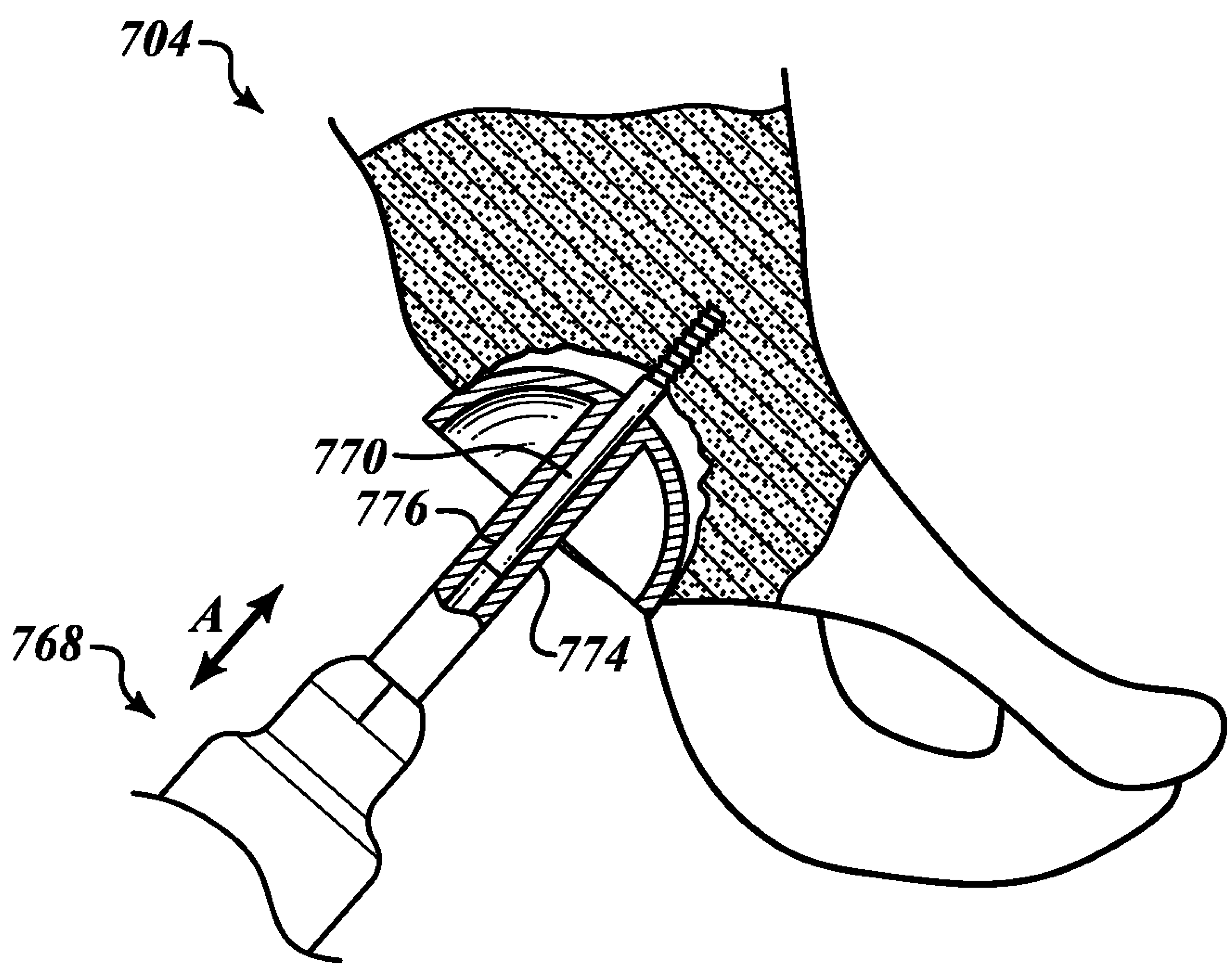

FIG.14

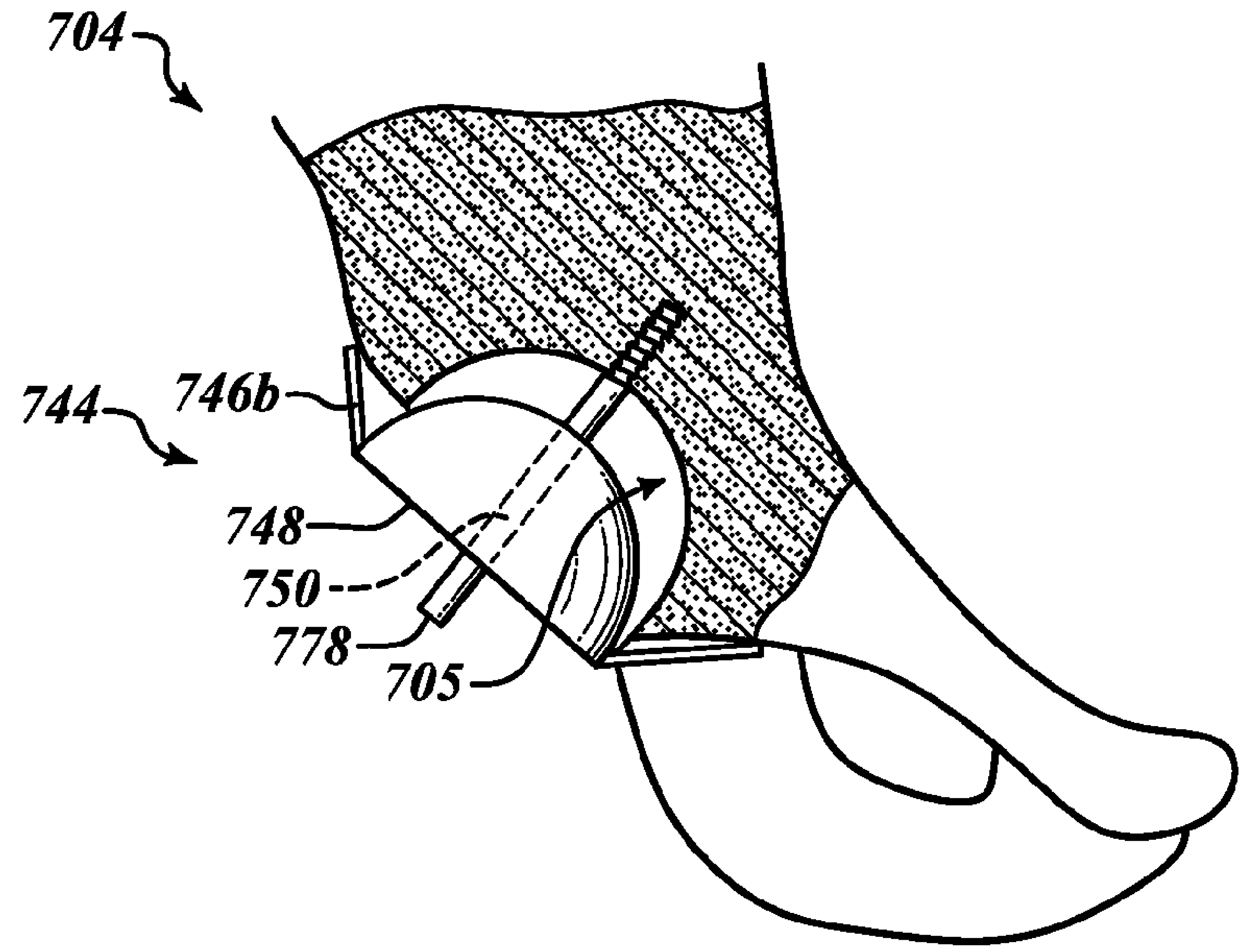

FIG.15A

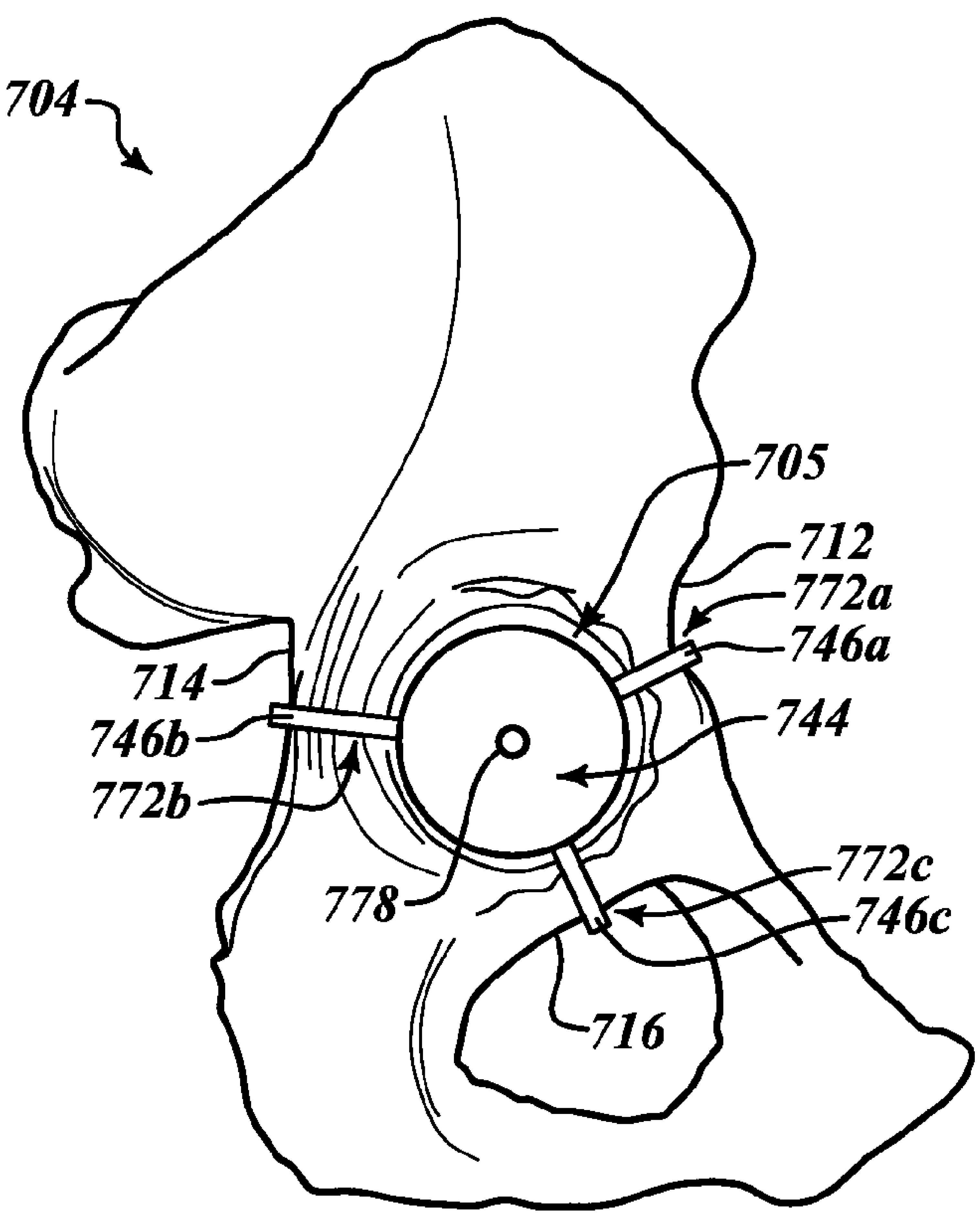

FIG.15B

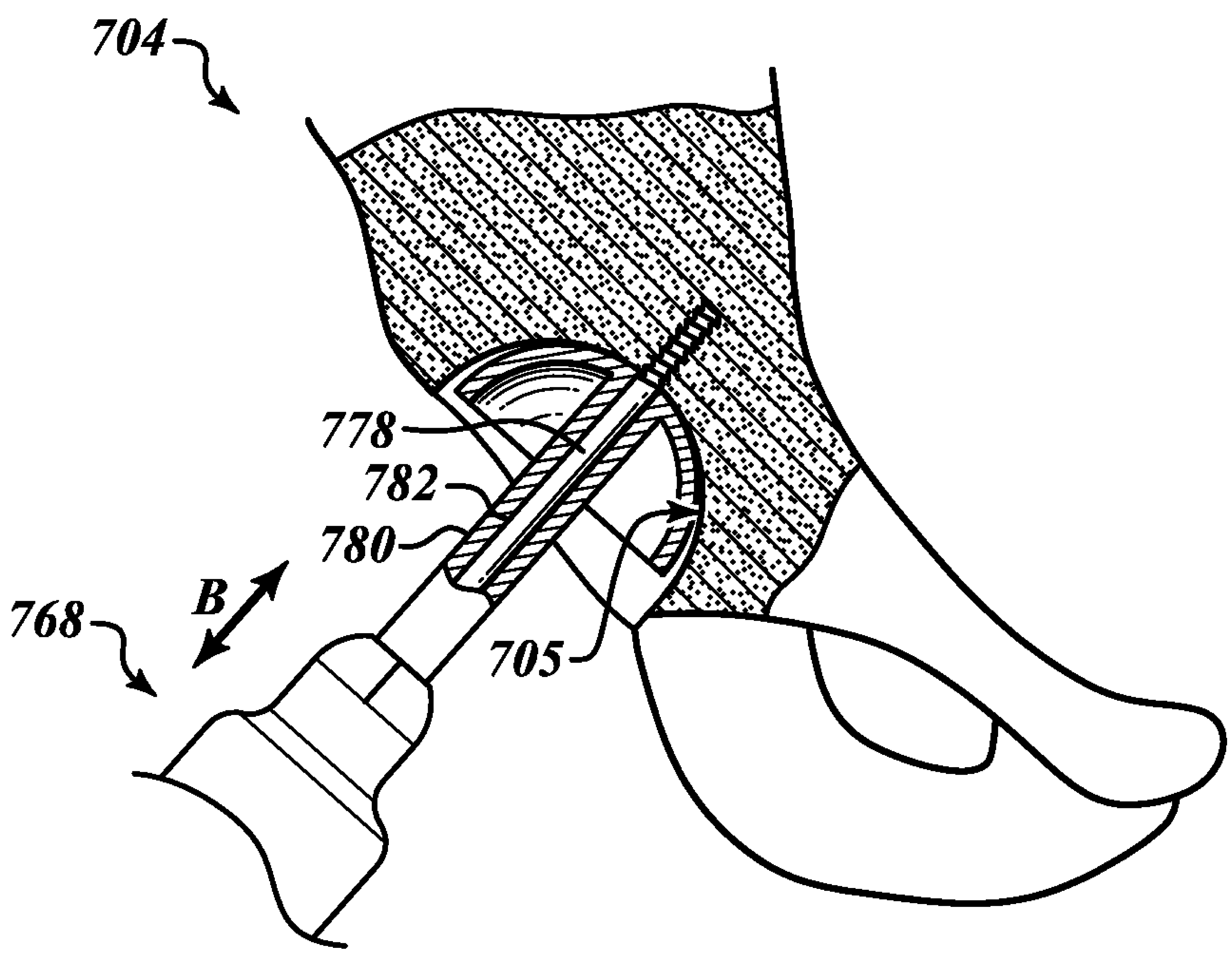

FIG.16

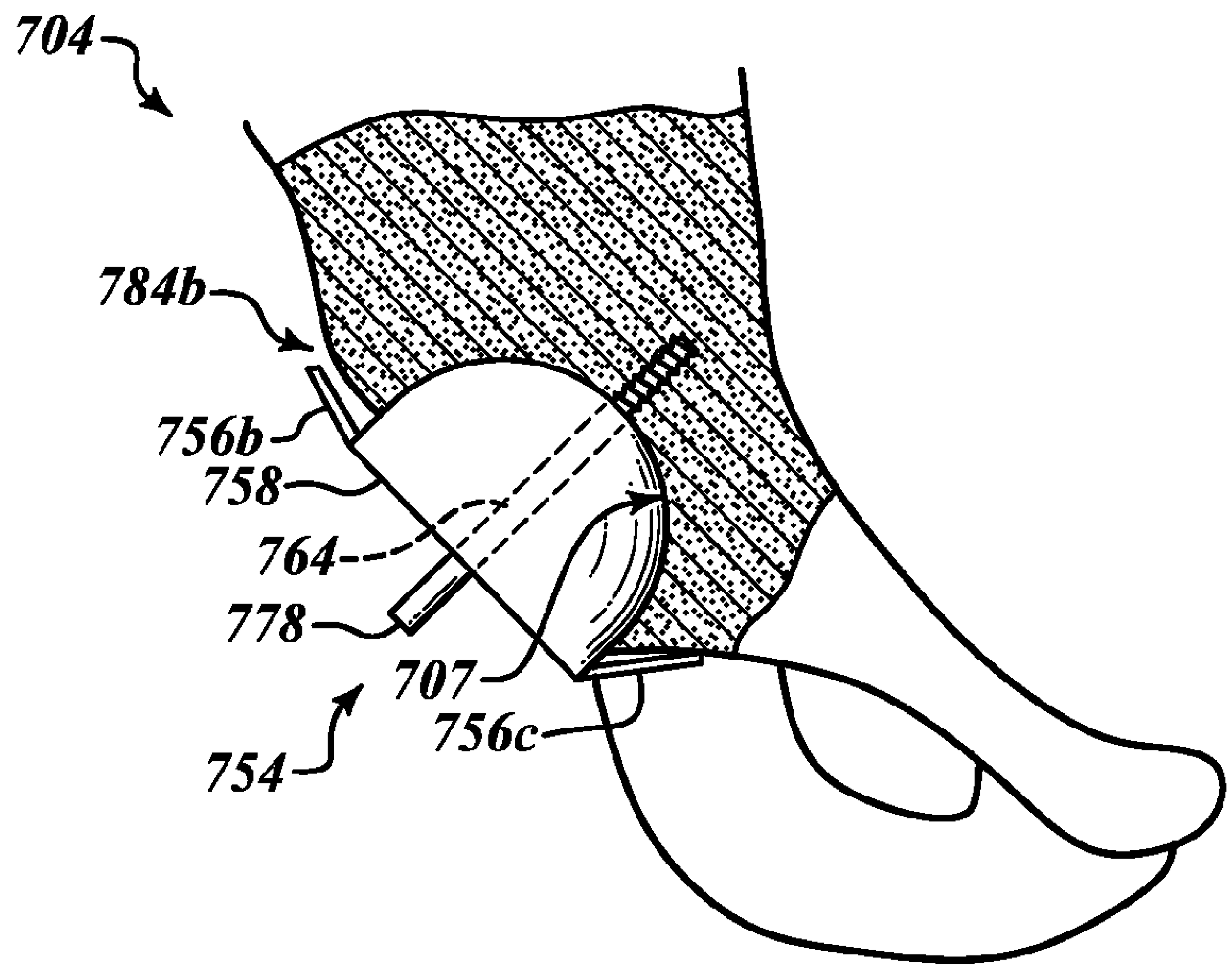

FIG.17A

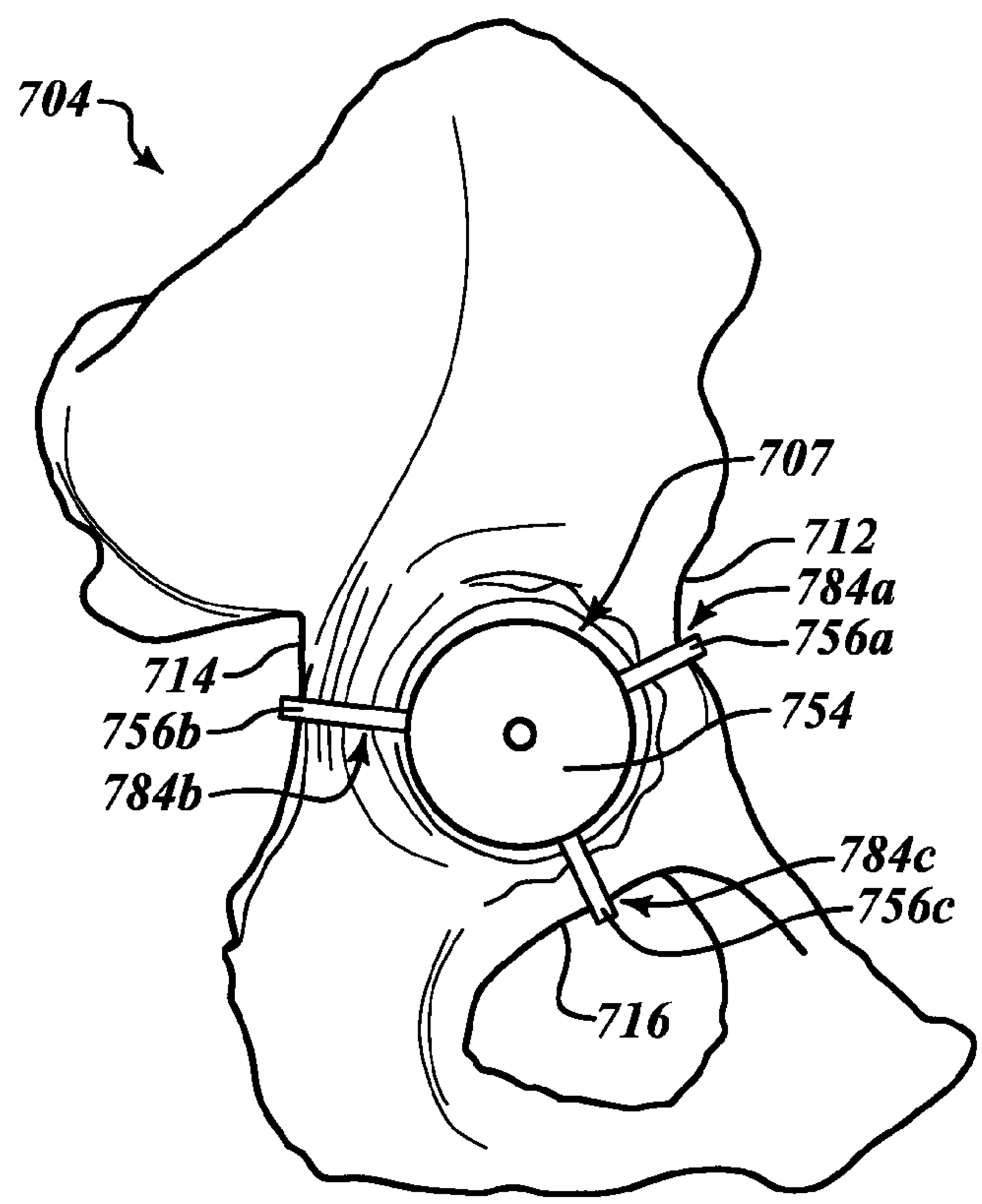

FIG.17B

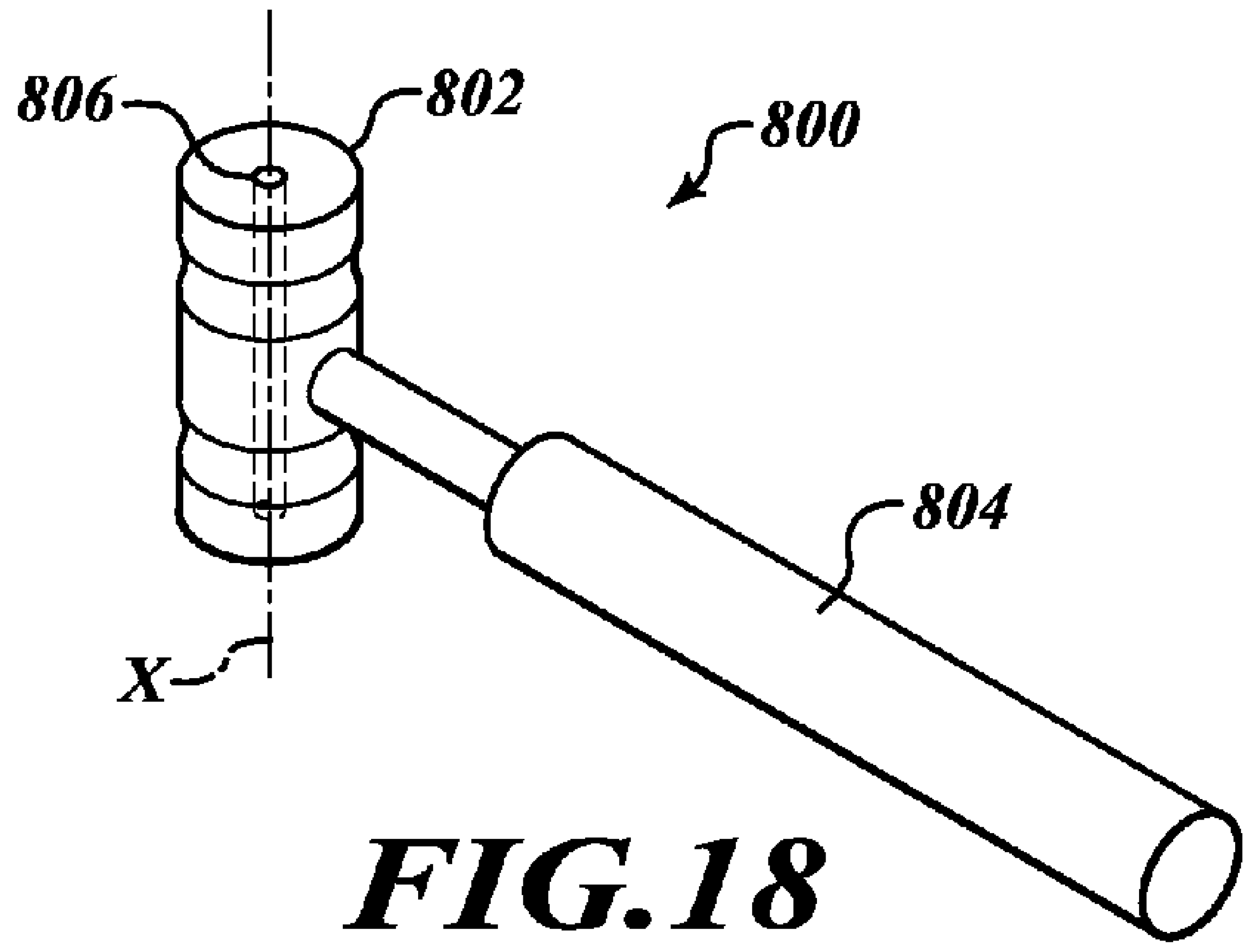

FIG.18

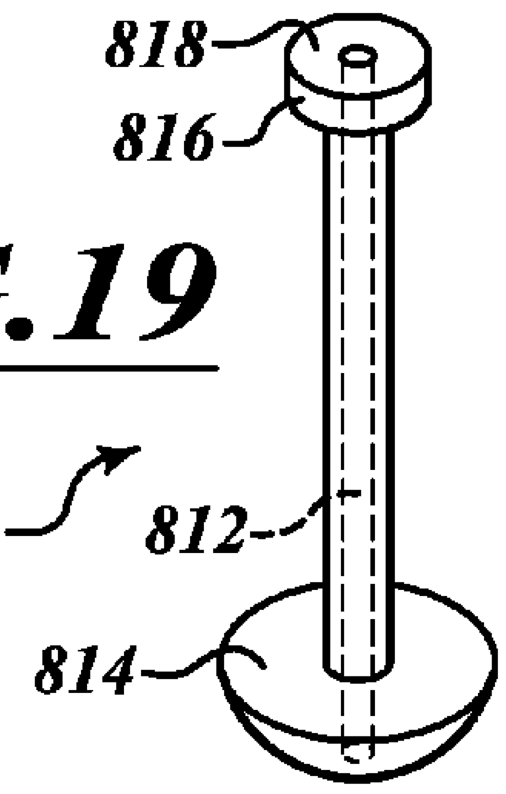

FIG.19

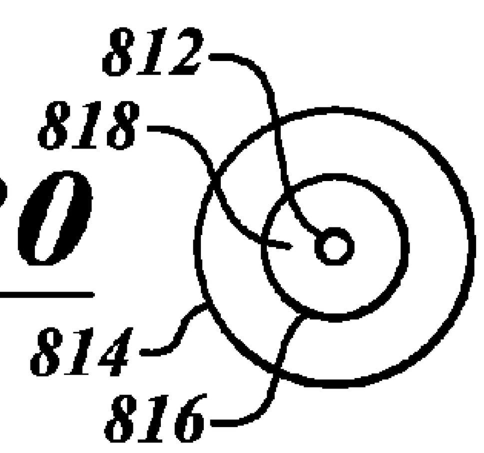

FIG.20

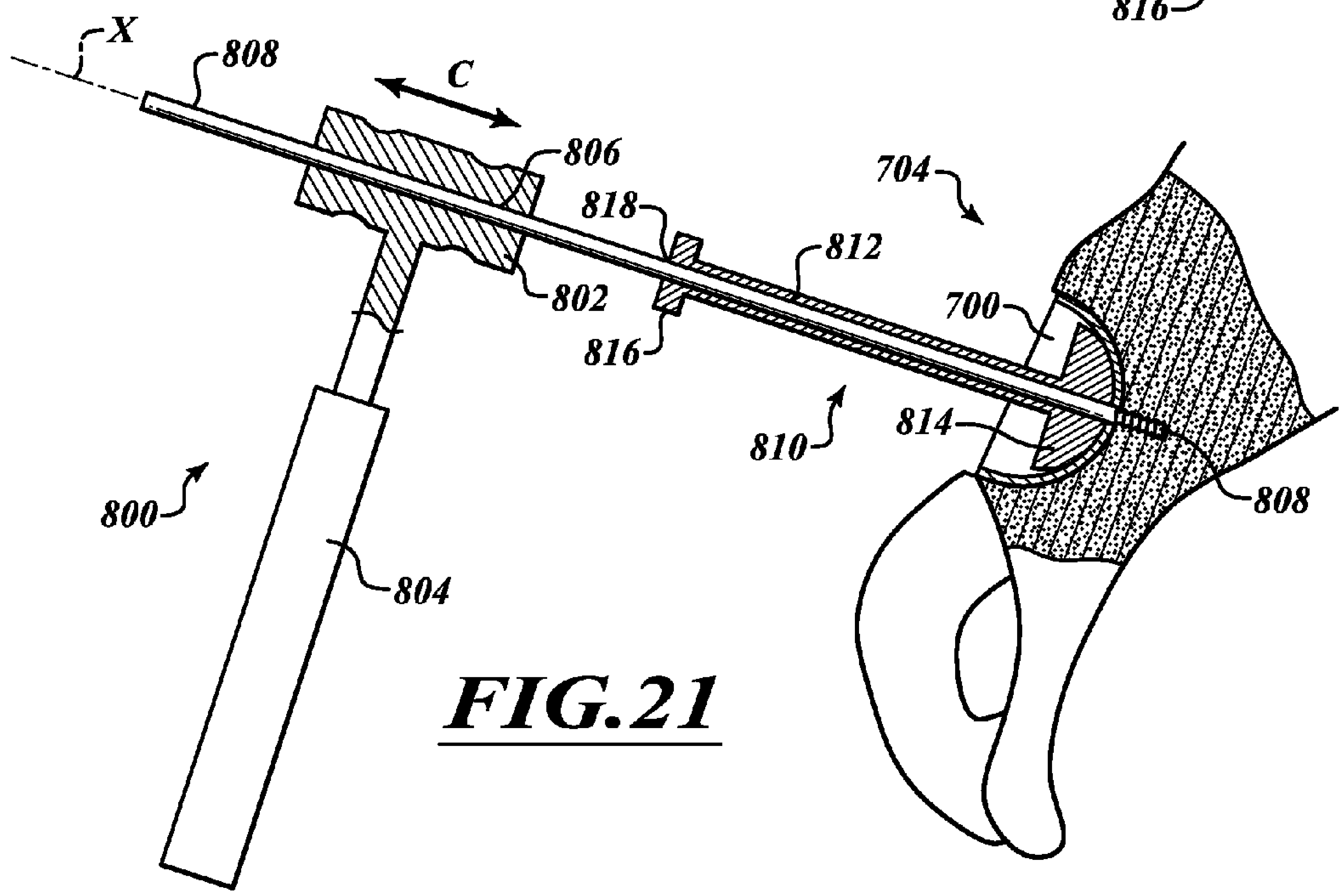

FIG.21

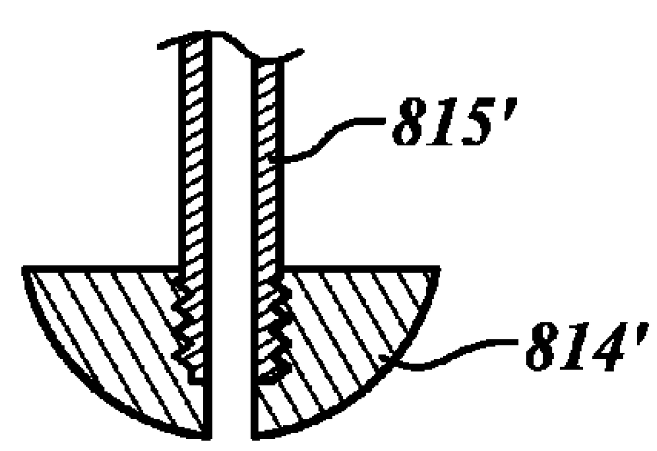

FIG.22

DEVICES AND METHODS FOR HIP REPLACEMENT

BACKGROUND

1. Technical Field

The present disclosure relates to devices and methods for the replacement of joints, and more particularly, to patient-specific hip replacement devices, including methods of manufacturing and using such devices for achieving accurate hip replacement based on computer generated imaging of a patient.

2. Background of the Invention

One known method of treating hip and other joints with arthritis and other medical conditions is to replace surfaces of articulating joints with prosthetic devices through surgical procedures. It is critical that such prosthetic devices are accurately designed and manufactured, and are installed correctly in order to relieve pain and provide an effective treatment method for such ailments. An orthopedic surgeon performing such joint replacement on a patient seeks to ensure, through surgery, adequate placement of the prosthetic and proper reconstruction of the joint being replaced. Prosthetic components used to replace a joint may placed optimally by templates and jigs according to the unique anatomy of a patient before surgery occurs. A particular patient's bone structure symmetry is one important consideration that a surgeon must consider when performing joint replacement surgery. Additionally, malposition of joint replacement prosthetics can result in premature wear of the bearing surfaces, which may require additional surgeries to correct.

In the case of a hip, the condition of the patient's joint may require a partial or total replacement. A partial hip replacement involves replacing the femoral head (the ball) of the damaged hip joint; however, the acetabulum (the socket) is not replaced in a partial hip replacement surgery. A total hip replacement includes replacing both the femoral head and the acetabulum with prosthetic devices. The femoral head is replaced with a femoral prosthetic that typically includes a head portion and a stem. The stem extends into the femur of the patient and is utilized to secure the femoral device to the femur, with the head portion protruding out from the femur. The acetabulum is then resurfaced and replaced with a cup-shaped acetabular device. The cup-shaped acetabular device provides a bearing surface for the head portion of the femoral prosthetic to allow a desirable amount of range of motion via the joint upon total hip replacement.

To replace the acetabulum effectively, a surgeon will typically enlarge the acetabulum with a reamer machine and reamer head to create a resurfaced cavity to receive a prosthetic acetabular cup, which may or may not be secured by cement or bone screws. One particular issue of concern during the reaming portion of the surgery is that the cutting portion of the reamer is hemispherical while the prosthetic acetabular cup is typically sub-hemispherical. If the acetabulum is reamed too deeply, the prosthetic acetabular cup will be positioned too deep within the reamed cavity. If the acetabulum is reamed too shallowly, the prosthetic acetabular cup will not be positioned deep enough. If the acetabulum is reamed at an improper angle, the prosthetic acetabular cup will not be installed properly. These imperfections can cause malalignment of the prosthetic hip joint. Thus, accurate reaming of the acetabulum and accurate positioning of the prosthetic acetabular cup are critical.

With the assistance of computer generated data derived from CT, MRI, or other scans, surgeons can more effectively determine proper alignment and positioning of the prosthetic acetabular cup in a patient through 3D modeling and rendering. While some surgeons use lasers during surgery in an attempt to properly place the prosthetic acetabular cup; however, accuracy and simplicity of existing devices and methods remain limited due to a variety of factors.

BRIEF SUMMARY

The present disclosure pertains to patient-specific hip replacement devices and methods of designing and manufacturing such devices for achieving accurate acetabular component placement during hip replacement surgery based on computer generated imaging of a particular patient. When an orthopedic surgeon recommends total hip replacement surgery for a particular patient, a variety of images may be obtained utilizing CT, MRI, and other scans to generate 3D modeling of the patient's bone structure, particularly the femur, the pelvic bone, and the coxal (hip) bone. From such 3D models, the surgeon may determine the specific, final location and orientation of an acetabular cup to be secured to the patient's acetabulum during surgery. Once the final location and orientation of the acetabular cup is determined, the surgeon (utilizing 3D images) may create a first patient-specific jig and a second—and in some cases a third—patient-specific jig to be inserted into the patient's acetabulum during the surgery to ultimately achieve accurate positioning of the prosthetics to be installed in the patient.

The first patient-specific jig may be designed and manufactured based on a first patient-specific acetabulum male portion, while the second patient-specific jig may be designed and manufactured based on a second patient-specific acetabulum male portion. The first and second patient-specific acetabulum male portions can be developed as either physical components via a prototyping machine or visual representations in a 3D modeling software program based upon the 3D images of the patient. The male portion may or may not fully contact the patient's native acetabulum.

The first patient-specific jig can be a hemispherical shaped device or a sub-hemispherical shaped device, and can be comprised of composite material or other materials. The first patient-specific jig may include at least three alignment members for attachment to specific portions of the jig based on the specific bone structure of the patient's coxal bone. The at least three alignment members may assist with proper alignment of the first patient-specific jig in the patient's acetabulum during surgery. The three alignment members may include first, second, and third alignment members that are positioned at specific outer portions of the first patient-specific jig.

In some embodiments, the first, second, and third alignment members are designed and adapted to be hooked on or engaged with (or otherwise positioned at) particular portions of the coxal bone adjacent to the acetabulum to stabilize and properly orient the first patient-specific jig into the acetabulum during surgery. The first alignment member may be positioned on the first patient-specific jig to engage a particular portion of the medial rim of the acetabulum of the coxal bone. The second alignment member may be positioned on the first patient-specific jig to engage a particular portion of the greater sciatic notch of the coxal bone. The third alignment member may be positioned on the first patient-specific jig to engage a particular portion of the obturator foramen of the coxal bone. These alignment members may contact any three areas of bone peripheral to the acetabulum. Thus, the first patient-specific jig includes three reference points/members, specific to the patient's acetabulum of the coxal bone, to properly align the first patient-specific jig in the acetabulum during surgery and provide for proper orientation of the reaming machine when resurfacing the acetabulum.

The three alignment members may each comprise a pair of hooks or other devices that provide sufficient engagement with the particular portions of the coxal bone, as determined by the surgeon during preoperation. A person having ordinary skill in the art when reviewing this disclosure will understand that the three alignment members may be secured or removably attached or abutted to the first patient-specific jig by any currently or later known suitable means or attachment methods. The three alignment members may pivot, swivel or otherwise move relative to the first patient-specific jig, or they may be relatively immovable or inflexible to provide sufficient force against respective portions of the coxal bone to ensure proper orientation of the first patient-specific jig.

An aperture may be provided radially into or through the first patient-specific jig. The aperture is adapted to receive a guide pin or post extension through the aperture during surgery. The guide pin or extension is placed into the aperture and is removably secured to the coxal bone of the patient in a particular orientation and at a particular depth, as determined by the surgeon during preoperation. The first patient-specific jig is then removed while the guide post remains positioned in the coxal bone at the desired angle and position. The guide post may then serve as a guide for the reaming machine to accurately ream (resurface) the acetabulum to a predetermined depth and orientation for receiving the acetabular cup. The guide post and the reamer may have the same or similar central axes, as with conventional reaming machines and processes. In some embodiments the guide post may be removed prior to reaming and a surgeon at his discretion may use the guide post sinus tract as a guide to reaming without the guide post at a desired angle and to a desired depth.

As discussed above, it is critical to ream the acetabulum accurately and as determined during preoperation. Accordingly, the second patient-specific jig may be provided to assist in determining accurate reaming and proper alignment of the acetabular cup before the cup is implanted into the patient's acetabulum. As indicated below, a third patient-specific jig may also be used to progressively prepare the acetabulum to properly receive the prosthetic acetabular cup.

The second patient-specific jig may be designed and manufactured based on the second patient-specific male portion, but it may also be based on the first patient-specific male portion. The second patient-specific jig may include at least three alignment members, which may be based on the same or similar positions as the first, second, and third alignment members of the first patient-specific jig, or the positions may be different depending upon the patient's anatomy. The second patient-specific jig may also include an aperture having the same or similar position and orientation as the aperture in the first patient-specific jig, or it may be different. The second patient-specific jig may also have an axial length that is greater than a corresponding axial length of the first patient-specific jig due to the fact that the second patient-specific jig is utilized after some or all of the reaming of the acetabulum has occurred.

After the surgeon has removed the first patient-specific jig and reamed the acetabulum to a predetermined depth and orientation, the reamer device is removed from the acetabulum and the guide post may remain attached to the coxal bone or, in some instances, may be removed. The surgeon may then position the second patient-specific jig into the reamed acetabulum without a pin or, alternatively, onto the original guide pin or post extension, or alternatively over a different pin or post extension used to align the second patient-specific jig. Using the particular shape and size of the second patient-specific jig and, where applicable, the alignment of the aperture through the jig, the surgeon may then rotate and position the second patient-specific jig in the reamed acetabulum to determine whether additional reaming is required in one or more quadrants, or whether the acetabulum has been reamed accurately to receive the prosthetic acetabular cup. In furtherance of such determination, the surgeon may also utilize the alignment members attached to the second patient-specific jig, if they were designed and manufactured for attachment to the jig; it may be that the aperture and the shape of the second patient-specific jig is sufficient for purposes of accurate alignment of the prosthetic acetabular cup.

In some instances, if adequate remaining in any direction has not been accomplished and confirmed with only one or two jigs, there may be a need for additional reaming after which a third jig may be used. The third patient specific jig may be similar or different in regards to alignment members and guide post aperture orientation as the first and/or second patient specific jigs.

Once accurate reaming is accomplished through utilizing some or all of the above described devices and methods, the surgeon may then implant or secure the acetabular prosthetic cup to the reamed acetabulum in a traditional manner, such as with or without screws and with or without cement and with or without use of a guide pin or post extension.

The predetermined orientation of the apertures and the alignment members of both the first and second (and, as applicable, third) patient-specific jigs may provide the surgeon with a quick, accurate means to properly resurface the acetabulum without the use of additional devices and machines. This is possible because the positions of the alignment members of the first, second and third patient-specific jigs are based upon the patient's bone structure, thereby providing three reference points to accurately utilize the first jig, the guide post, the reamer, and the second and third jigs, as planned during preoperation based upon the 3D modeling images of the patient.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

FIGS. **1-4** are flow diagrams illustrating steps for preoperative imaging and planning for a joint replacement procedure, according to an aspect of the present invention.

FIG. **4**A schematically illustrates a system for carrying out the steps of FIGS. **1-4**.

FIGS. **5** and **6** are flow diagrams illustrating steps for performing a joint replacement procedure, according to an aspect of the present invention.

FIG. **7** is a front view of a pelvic bone.

FIG. **8** is a top view of a prosthetic implant seated in the pelvic bone of FIG. **7**.

FIG. **9**A is a top view of a patient-specific jig mounted on the pelvic bone of FIG. **7** according to one embodiment.

FIG. **9**B is a partial cross-sectional view of the pelvic bone of FIG. **7** and a side view of the patient-specific jig of FIG. **9**A.

FIG. **10**A is an isometric view of a first patient-specific jig according to one embodiment.

FIG. **10**B is an elevational view of the first patient-specific jig of FIG. **10**A.

FIG. **11**A is an isometric view of a second patient-specific jig according to one embodiment.

FIG. **11**B is an elevational view of the second patient-specific jig of FIG. **11**A.

FIG. **12**A is an isometric view of a third patient-specific jig according to one embodiment.

FIG. **12**B is an elevational view of the third patient-specific jig of FIG. **8**.

FIG. **13**A is a side view of a first patient-specific jig positioned in an acetabulum and a guide post positioned through said jig and secured to the acetabulum.

FIG. **13**B is a side view of the pelvic bone showing the first patient-specific jig positioned in the acetabulum.

FIG. **14** is a cross-sectional view of a reaming tool positioned in the acetabulum.

FIG. **15**A is a side view of a second patient-specific jig positioned in an acetabulum and a supplemental guide post positioned through said jig and secured to the acetabulum.

FIG. **15**B is a side view of the pelvic bone showing the second patient-specific jig positioned in the acetabulum **15**A.

FIG. **16** is a cross-sectional view of a reaming tool positioned in the acetabulum.

FIG. **17**A is a side view of a third patient-specific jig positioned in the acetabulum and the supplemental guide post of FIG. **15**A.

FIG. **17**B is a top view of the third patient-specific jig positioned in the acetabulum as shown in FIG. **17**A.

FIG. **18** is an isometric view of an impactor tool used to install a prosthetic implant in a reamed acetabulum according to one aspect of the present disclosure.

FIG. **19** is an isometric view of a cannulated acetabular impactor according to an embodiment of the present invention.

FIG. **20** is an end view of the cannulated acetabular impactor of FIG. **19**.

FIG. **21** is a partial cross-sectional view of a prosthetic implant in a reamed acetabulum that is being installed with the impactor tool of FIG. **18** and the cannulated actabular impactor of FIG. **19**, according to one aspect of the present disclosure.

FIG. **22** is a cross-sectional view of a portion of another cannulated acetabular impactor according to an alternate embodiment of the invention.

DETAILED DESCRIPTION

As mentioned above, the methods and systems of the present invention are based at least in part on pre-operating (pre-operative) imaging and at least in part on orthopedic surgical procedures based upon the pre-operative methods and systems. As is understood in the art, pre-operative imaging has a number of different purposes and generally is performed in order to subsequently guide the surgeon during the surgical procedure, allow for patient-specific tools and/or implants to be formed, etc. The present disclosure is part of a system for designing and constructing one or more patient-specific jigs for use in an orthopedic surgical procedure in which an acetabular component is prepared, orientated and implanted. The referenced systems and methods are now described more fully with reference to the accompanying drawings, in which one or more illustrated embodiments and/or arrangements of the systems and methods are shown. Aspects of the present systems and methods can take the form of an entirely hardware embodiment, an entirely software embodiment (including firmware, resident software, micro-code, etc.), or an embodiment combining software and hardware. One of skill in the art can appreciate that a software process can be transformed into an equivalent hardware structure, and a hardware structure can itself be transformed into an equivalent software process. Thus, the selection of a hardware implementation versus a software implementation is one of design choice and left to the implementer. Throughout this disclosure, the term "prosthetic implant" and "acetabular component" refer to cup-shaped implants that are installed into patients during hip replacement surgery.

FIGS. **1-4** are flow diagrams illustrating methods pertaining to pre-operative imaging and planning according to aspects of the present invention. FIG. **4**A shows a system for carrying out the methods of the present disclosure, such as those described with reference to FIGS. **1-4**. As a preliminary matter, FIG. **4**A is a simplified system **410** of devices that may be used to carry out the methods of the present disclosure. The system **410** comprises a computing system **412** coupled to an imaging system **414** that captures and transmits patient image data to the computing system **412**. The computing system **412** processes such data and transmits the data to the display device **416** for display of images and other data. An input device **418** receives input from a computer or an operator (such as a surgeon) and transmits inputted information to the computing system **412** for processing. Such systems are well known in the art and will not be described in greater detail. The imaging system **412** may include a bone imaging machine for forming three dimensional image data from bone structure of a patient. The computing system **412** may include a patient-specific device generator for processing and generating images, and a patient-specific device converter for generating design control data. A manufacturing machine **420** receives the control data from the computing system **412** for making patient-specific various jigs.

In FIG. **1**, a method **100** according to an embodiment starts at **101**. At **102**, a bone imaging machine generates a bone surface image from three dimensional image data from bone structure of a patient. At **104**, a patient-specific device generator generates a prosthesis implant image superimposed in an acetabulum of the bone surface image. The implant in the image is positioned in its final, implanted position and orientation, regardless of the state of the patient's bone. The jigs created from the present invention will be designed to modify the bone such that the implant will be properly positioned at the end of the procedure.

At **106**, the patient-specific device generator generates a first-patient specific jig image superimposed proximate the acetabulum of the bone surface image according to the installation position. At **108**, a patient-specific device converter generates control data from the first patient-specific jig image and ends or moves to **110**. At **110**, the patient-specific device generator generates a second patient-specific jig image superimposed in the acetabulum of the bone surface image and ends or moves to **112**. At step **112**, the patient-specific device generator generates a third patient-specific jig image superimposed in the acetabulum of the bone surface image and ends.

FIG. **2** shows a method **200** according to an aspect of the present disclosure. At **202**, a patient-specific device generator generates a guide post image at least partially positioned through an acetabulum of the bone surface image. At **204**, the patient-specific device generator generates a first patient-specific jig image superimposed in the acetabulum of the bone surface image according to the installation position. At **206**, the patient-specific device generator generates an aperture image through the body image of the second patient-specific jig image and ends.

FIG. **3** shows a method **300** according to an aspect of the present disclosure. At **302**, a patient-specific device generator generates a guide post image at least partially positioned through an acetabulum of the bone surface image. At **304**, the patient-specific device generator generates a second patient-specific jig image superimposed in the acetabulum of the bone surface image according to the installation position. At

306, the patient-specific device generator generates an aperture image through the body image of the first patient-specific jig image and ends.

FIG. 4 shows a method 400 according to an aspect of the present disclosure. At 402, a patient-specific device generator generates a guide post image at least partially positioned through an acetabulum of the bone surface image. At 404, the patient-specific device generator generates a third patient-specific jig image superimposed in the acetabulum of the bone surface image according to the installation position. At 306, the patient-specific device generator generates an aperture image through the body image of the third patient-specific jig image and ends.

As discussed above, FIG. 4A shows a system 410 for carrying out the methods of FIGS. 1-4 according to some aspects of the present disclosure. The computing system 412 may include instructions in the form of computer software for automatically generating images of prosthesis implants in final installation positions on the bone structure images and for automatically generating various guide post images and jig images designed for use during surgery on the particular patient. In some aspects, it may be necessary for the surgeon during preoperative planning to input information into the input device 418 for creating or altering guide post and jig images for a particular patient based on the surgeon's understanding of the particular bone structure of the patient as displayed on the display device 416.

FIGS. 5 and 6 are flow diagrams of methods pertaining to operative surgery according to aspects of the present disclosure. The methods of FIGS. 5 and 6 may be carried out by a surgeon or by a machine, or by both. Moreover, the surgeon may utilize some or all of the devices discussed with reference to FIGS. 1-4A during surgery, such as viewing the preoperative images displayed on the display device while operating on a patient.

In FIG. 5, a method 500 according to an aspect starts at 501. At 502, a first patient-specific jig is positioned in an acetabulum of a patient. The first patient-specific jig is formed according to a predetermined installation position of a prosthesis implant to be secured to the patient. At 504, each of three alignment members is engaged with a corresponding pre-selected area on a coxal bone and adjacent the acetabulum of the patient. At 506, a guide post is positioned through the aperture of the first patient-specific jig and is secured into the coxal bone of the patient. At 508, the first patient-specific jig is removed from the guide post. At 510, bone material from the acetabulum is reamed with aid of a reaming machine. At 512, it is determined whether the reaming machine has reached an installation reference point of the installation position; this may be determined by the surgeon or by a measuring device or other device to determine the depth of bone that was reamed. If the reaming machine has reached an installation reference point, at 514 the guide post is removed and the prosthesis implant is installed in the patient, then ends. If the reaming machine has not reached an installation reference point, at 516 the guide post is removed and a second patient-specific jig is positioned in the reamed acetabulum of the patient, then to step 602 in FIG. 6. As further discussed below, in some aspects the guide post is not removed and remains secured to the patient until the prosthesis implant is installed.

At step 602, three alignment members of the second patient-specific jig are respectively engaged with predefined selected areas proximate the acetabulum of the patient. At 604, a supplemental guide post is positioned through the aperture of the second patient-specific jig and is secured into the coxal bone of the patient. At 606, the second patient-specific jig is removed from the supplemental guide post and the acetabulum. At 608, the acetabulum is reamed with aid of a reaming machine. In some instances the guide post can be removed prior to reaming and the sinus tract in the bone from the guide post is used as a visual guide to ream at a desired orientation and to a desired depth. At 610, a third patient-specific jig is positioned in the reamed acetabulum of the patient. At 612, it is determined whether all three alignment members of the third patient-specific jig are engaged to respective selected areas proximate the acetabulum of the patient. If yes, at 616 the supplemental guide post may or may not be removed and the prosthesis implant is secured to the reamed acetabulum and then ends. If no, the method returns to 608 and the operations are repeated until it is determined that all three alignment members of the third patient-specific jig are engaged to respective selected areas proximate the acetabulum of the patient so that the prosthesis implant may be installed in the patient.

FIGS. 7 and 8 show an acetabular component 700 oriented an in an acetabulum 702 of a coxal bone 704 of a pelvic bone 706. The acetabular component 700 is positioned according to an installation position 708, which is in part determined by a prescribed anteversion angle and a prescribed inclination angle of the acetabular component 700. FIG. 7 shows a front view of the pelvic bone 706 and the acetabular component 700 positioned in the acetabulum 702 of the patient's right coxal bone 704, and FIG. 8 shows a lateral view of the right coxal bone 704 with the acetabular component 700 positioned in the acetabulum 702. These figures illustrate the incorporation of steps discussed with reference to FIGS. 1-4A where the acetabular component 700 is a generated image that is superimposed over a generated image of bone structure (e.g., the coxal bone 704) of a patient to determine an installation position 708 of the acetabular component 700. Determining the prescribed anteversion angle and the prescribed inclination angle for a particular patient involves techniques and calculations that are known in the art, and thus, will not be described in detail. Although not necessarily part of the preoperative planning, for purposes of illustration an installation axis P is shown on FIG. 7

Once the installation position 708 is determined, a reference point 710 is established that represents a particular point in the coxal bone 704 of the patient for purposes of determining the depth to which a reaming machine will ream bone material, which will be further discussed below. The reference point 710 may be considered a point on the tangential plane of a hemispherical shaped surface, such as the outer surface shape of the acetabular component 700.

With continued reference to FIG. 8, the coxal bone 704 includes (among many others) a medial rim 712, a sciatic notch 714, and an obturator foramen 716, which all have various shapes and surfaces that are specific to each patient.

FIGS. 9A and 9B show a patient-specific jig 720 oriented in the acetabulum 702 of the coxal bone 704 according to the installation position 708 of the acetabular component 702. These figures show a technique that incorporates steps of FIGS. 1-4A in that the patient-specific jig 720 is a generated image that is superimposed over the generated image of the bone structure of a patient. As a preliminary matter, the patient-specific jig 720 may be any one of the first, second, and third patient-specific jigs discussed with reference to FIGS. 10A-15B and elsewhere in this disclosure. FIGS. 9A and 9B are mere illustrations of one possible patient-specific jig 720.

The patient-specific jig 720 includes an aperture 722 and three alignment members 724*a*, 724*b*, 724*c*. The aperture 722 is formed through the patient-specific jig 720 at an angle that corresponds to the installation position 708 of the acetabular component **700**. Depending upon the particular patient-specific jig **720** (i.e., the first, second, or third), the relative orientation of the aperture **722** may vary depending upon the required amount of bone to be removed and the particular required angle of a reaming head during operation, which is ultimately determined by the installation position **708** of the acetabular component **700**. The angles of the various apertures for the various jigs are discussed further below.

The three alignment members **724***a*, **724***b*, **724***c* are attached to the patient-specific jig **720** at positions around a circumference end **726** (or distal end) of the patient-specific jig **720** depending upon the particular bone structure of the particular patient. The three alignment members **724***a*, **724***b*, **724***c* may be formed integral with the jig or may be attached to the jig with any suitable attachment means. The purpose of the three alignment members **724***a*, **724***b*, **724***c* help the surgeon: 1) determine the proper orientation of a guide post to be installed in the patient (FIGS. **13**A and **15**A), and/or 2) determine whether additional reaming of bone is necessary before utilizing another jig or before final installation of an acetabular component. In any event, depending on whether all of the three alignment members **724***a*, **724***b*, **724***c* of a particular patient-specific jig **720** are in contact with respective selected areas of the patient's bone during surgery when the particular jig is placed in the acetabulum **702**, corresponding information is conveyed to the surgeon. The surgeon will be able to determine the next appropriate steps during surgery, as further described below.

The positions of the three alignment members **724***a*, **724***b*, **724***c* will depend on which particular jig (i.e., first, second, or third jigs) the three alignment members are attached to. However, the positions the three alignment members **724***a*, **724***b*, **724***c* may be the same on each jig depending on the preoperative requirements determined by the surgeon and the computing systems. In one example and as shown on FIG. **9**B, the first alignment member **724***a* is attached to the patient-specific jig **720** at an attachment portion **726***a*, and the second alignment member **724***b* is attached to the patient-specific jig **720** at an attachment portion **726***b*, and the third alignment member **724***c* is attached to the patient-specific jig **720** at an attachment portion **726***c*. The position of the respective attachment portions **726***a*, **726***b*, **726***c* are determined during pre-operative imaging and planning steps. Accordingly, the three alignment members **724***a*, **724***b*, **724***c* extend from the circumference end **726** of the patient-specific jig **720** and are designed to contact certain selected areas of the coxal bone **704** depending on the bone structure of the patient. The first alignment member **724***a* contacts a selected area **728***a* of the medial rim **712**. The second alignment member **724***b* contacts a selected area **728***b* of the sciatic notch **714**. Finally, the third alignment member **724***c* contacts a selected area **728***c* inferiorally below the transverse acetabular ligament at the superior portion of the obturator foramen **716**. In some instances, such as when using the second and third jigs, the contact between the alignment members and the respective selected areas is dependent upon whether the surgeon has reamed enough bone. If not, at least one of the alignment members will not be in contact with the respective selected area, indicating that more bone needs to be removed, as further discussed below.

FIGS. **10**A and **10**B show a first patient-specific jig **730**. FIGS. **11**A and **11**B show a second patient-specific jig **744**. FIGS. **12**A and **12**B show a third patient-specific jig **754**. These figures represent that the patient-specific jigs are generated images based on the installation position of the acetabulum component and based on the bone structure of the patient. Some or all of the patient-specific jigs are formed by a machine based on the generated images, as further discussed elsewhere in this disclosure. In some cases, only a first patient-specific is generated and created in instances where very little bone reaming is required, for example.

FIG. **10**A shows an isometric view of a first patient-specific jig **730** and FIG. **10**B shows a side elevational view of FIG. **10**A. The first patient-specific jig **730** includes three alignment members **732***a*, **732***b*, **732***c* that extend from a circumference end **734** of the first patient-specific jig **730** at positions to contact certain selected areas of the coxal bone (see FIG. **9**A (generically) and FIG. **13**B (specifically)). The first alignment member **732***a* is attached to the patient-specific jig **730** at an attachment portion **736***a*, and the second alignment member **732***b* is attached to the first patient-specific jig **730** at an attachment portion **736***b*, and the third alignment member **732***c* is attached to the patient-specific jig **730** at an attachment portion **736***c*. The angle and position of each alignment member **732***a*, **732***b*, **732***c* relative to the circumference end **734** is determined according to the particular position and surface of the selected areas of the coxal bone of the patient that the alignment members **732***a*, **732***b*, **732***c* are designed to contact during use of the first patient-specific jig **730** during operation. Each alignment member **732***a*, **732***b*, **732***c* includes an engagement portion **738***a*, **738***b*, **738***c*, respectively, which is the portion of the alignment member that contacts respective selected areas of the coxal bone **704**. See FIGS. **13**A and **13**B for illustrations of the position of each alignment members **732***a*, **732***b*, **732***c* relative to the first patient-specific jig **730** and the selected areas of the patient's coxal bone **704**.

The first patient-specific jig **730** includes an aperture **740** that extends from a reference end **742** to the circumference end **734** of the first patient-specific jig **730**. The aperture **740** is sized and configured to receive a guide post positioned in a patient (FIG. **13**A). As further described below, the guide post is positioned according to the installation position **708** of the acetabular component **700** (FIGS. **7** and **8**). The first patient-specific jig **730** includes a height H**1**, which is selected so that the reference end **742** does not contact an unreamed acetabulum at the beginning stages of surgery. This is discussed further below.

FIG. **11**A shows an isometric view of a second patient-specific jig **744** and FIG. **11**B shows a side elevational view of FIG. **11**A. The second patient-specific jig **744** includes three alignment members **746***a*, **746***b*, **746***c* that extend from a circumference end **748** of the second patient-specific jig **744** at positions to contact certain selected areas of the coxal bone (see FIG. **9**A (generically) and FIG. **15**B (specifically)). The alignment members **746***a*, **746***b*, **746***c* are attached to the second patient-specific jig **744** at respective attachment portions **750***a*, **750***b*, **750***c*, similar to the first patient-specific jig **730**. The angle and position of each alignment member **746***a*, **746***b*, **746***c* relative to the circumference end **748** is determined according to the particular position and surface of the selected areas of the coxal bone of the patient that the alignment members **746***a*, **746***b*, **746***c* are designed to contact during use of the second patient-specific jig **744** during operation. Such angle and position of each alignment member **746***a*, **746***b*, **746***c* may be the same as or different than that of the alignment members of the first patient-specific jig **730** of FIG. **10**A. Each alignment member **746***a*, **746***b*, **746***c* includes an engagement portion **748***a*, **748***b*, **748***c*, respectively, which is the portion of the alignment member that contacts respective selected areas of the coxal bone **704**. See FIGS. **15**A and **15**B for illustrations of the position of each alignment member **746***a*, **746***b*, **746***c* relative to the second patient-specific jig **744** and the selected areas of the patient's coxal bone **704**.

The second patient-specific jig **744** includes an aperture **750** that extends from a reference end **752** to the circumference end **748** of the second patient-specific jig **744**. The aperture **750** is sized and configured to receive a supplemental guide post positioned in a patient (FIG. **15**A). As further described below, the supplemental guide post is positioned according to the installation position **708** of the acetabular component **700** (FIGS. **7** and **8**). The second patient-specific jig **744** includes a height H**2**, which is selected so that, if the reference end **752** contacts a reamed acebaulum, and if at least one of the alignment members **746***a*, **746***b*, **746***c* is not in contact with a respective selected area of the coxal bone, the surgeon will know that additional reaming is necessary before installing the supplemental guide post and placing the final acetabular prosthesis. This is discussed further below. Understandably, height H**2** can be greater than height H**1**, in part because bone is reamed between usage of the first and second jigs.

FIG. **12**A shows an isometric view of a third patient-specific jig **754** and FIG. **12**B shows a side elevational view of FIG. **12**A. The third patient-specific jig **754** includes three alignment members **756***a*, **756***b*, **756***c* that extend from a circumference end **758** of the third patient-specific jig **754** at positions to contact certain selected areas of the coxal bone (see FIG. **9**A (generically) and FIG. **17**B (specifically)). The alignment members **756***a*, **756***b*, **756***c* are attached to the third patient-specific jig **754** at respective attachment portions **760***a*, **760***b*, **760***c*, similar to the first patient-specific jig **730**. The angle and position of each alignment member **756***a*, **756***b*, **756***c* relative to the circumference end **758** is determined according to the particular position and surface of the selected areas of the coxal bone of the patient that the alignment members **756***a*, **756***b*, **756***c* are designed contact during use of the third patient-specific jig **754** during operation. Such angle and position of each alignment member **756***a*, **756***b*, **756***c* may be the same or different to that of the alignment members of the first and second patient-specific jigs of FIGS. **10**A and **11**A. Each alignment member **756***a*, **756***b*, **756***c* includes an engagement portion **762***a*, **762***b*, **762***c*, respectively, which is the portion of the alignment member that contacts respective selected areas of the coxal bone **704**. See FIGS. **17**A and **17**B for illustrations of the position of each alignment members **756***a*, **756***b*, **756***c* relative to the third patient-specific jig **754** and the selected areas of the patient's coxal bone **704**.

The third patient-specific jig **754** includes an aperture **764** that extends from a reference end **766** to the circumference end **758** of the third patient-specific jig **754**. The aperture **764** is sized and configured to receive the supplemental guide post positioned in a patient (FIG. **17**A). As further described below, the supplemental guide post is positioned according to the installation position **708** of the acetabular component **700** (FIGS. **7** and **8**). The third patient-specific jig **754** includes a height H**3**, which is selected so that, if the reference end **766** contacts a reamed acetabulum, thereby causing at least one of the alignment members **756***a*, **756***b*, **756***c* to not be in contact with a respective selected area of the coxal bone, the surgeon will know that additional reaming is necessary before installing the acetabular component **700** in the patient. This is discussed further below. Understandably, height H**3** can be greater than height H**2** because bone is reamed between usage of the second and third jigs, and because the second patient-specific jig is used for purposes of positioning the supplemental guide post while the third patient-specific jig is used for purposes of determining whether additional reaming is necessary before installing the acetabular component **700** in the patient.

It will be appreciated that each or all of the alignment members of any one of the patient-specific jigs may be formed in various configuration and shapes. For example, an alignment member may be an arc shaped or other non-linear shaped member, or it may have two or more angles surfaces. The exact shape, position, and alignment of each alignment member is determined by the surgeon and the computing system during preoperative planning depending upon the specific bone structure of the patient and the installation position of the acetabulum component.

FIGS. **13**A and **13**B show the first patient-specific jig **730** positioned in an un-reamed acetabulum **703** of the patient, and FIG. **14** shows a reaming tool **768** positioned in the acetabulum **703** and ready to ream bone material. These figures show a technique that incorporates the preoperative steps of FIGS. **1-4**A in that the first patient-specific jig **730** and a guide post **770** are generated images that are superimposed over the generated image of the bone structure of a patient. These figures also show a technique that incorporates the operative steps practiced by a surgeon on a patient, such as described with reference to FIGS. **5** and **6**.

During preoperative planning and with reference to FIGS. **9**A and **9**B, a generated image of an acetabular component **700** is imposed over the bone structure image, which ultimately shows the installation position **708** of the acetabular component **700**. Based on such installation position **708**, the computer system determines, with input from the surgeon, the exact position of the guide post **770** to be installed in the patient during early stages of operation. The guide post **770** will be the guide for the position of the first patient-specific jig **730** and the reaming machine **768**. Preferably, the guide post **770** is positioned substantially perpendicular to a central axis of the acetabular component **700** to be later installed in the patient; however, the angle of the guide post **770** relative to the acetabular component **700** may vary depending upon the preoperative surgery analysis by the computer system and the surgeon based on patient requirements. Once the orientation of the guide post **770** is established and displayed as a generated image, an image is generated of the first patient-specific jig **730**. As noted above, the purpose of the first patient-specific jig **730** is to establish the exact position of the guide post **770** to be installed in the patient during surgery. Accordingly, the reference end **742** of the first patient-specific jig **730** is designed to make contact with the un-reamed acetabulum **703**. The three alignment members **732***a*, **732***b*, **732***c* are designed to contact respective selected areas of the coxal bone **704** adjacent the acetabulum **703**.

With particular reference to FIGS. **13**B, during surgery the surgeon inserts the first patient-specific jig **730** into the acetabulum **703** and rotates or otherwise orients the first patient-specific jig **730** in the patient until all three alignment members **732***a*, **732***b*, **732***c* are in contact with respective selected areas **772***a*, **772***b*, **772***c* of the coxal bone **704**. Once the first patient-specific jig **730** is properly oriented, the surgeon inserts the guide post **770** through the aperture **740** and screws the guide post **770** into the bone (typically 2 mm to 20 mm deep). Thus, the guide post **770** will be installed at the exact position determined during preoperative planning and according to the installation position of the acetabular component **700**. The first patient-specific jig **730** may then be removed and a reaming machine **768** may be used to remove bone material from the patient, either over the guide post or without it in place.

FIG. **14** illustrates the reaming machine **768** used for such purpose. The reaming machine **768** includes a reaming head **774**, which may be a detachable head of a selected size corresponding to the size of the acetabular component **700** to be installed. The reaming head **774** includes a guide aperture **776** that slidably receives the guide post **770**. The reaming head **774** reams bone with a consistent axial motion in a direction depicted by Arrow A because the guide aperture **776** includes a central axis coextensive with a central axis of the guide post **770** and because the guide aperture **776** closely receives the guide post **770**. Such reaming heads with a guide aperture and methods of using such reaming heads with a guide post in a patient are well known in the art and will not be described in greater detail.

FIGS. **15**A and **15**B show the second patient-specific jig **744** positioned in a reamed acetabulum **705** of the patient, and FIG. **16** shows a reaming tool **768** ready to ream additional bone material. These figures show a technique that incorporates the preoperative steps in that the second patient-specific jig **744** is a generated image that is superimposed over the generated image of the bone structure of a patient. These figures also show a technique that incorporates the operative steps practiced by a surgeon on a patient.

FIG. **15**A shows the reamed acetabulum **705** as the result of the surgeon reaming a portion of the acetabulum **703** to a desired depth. In some instances, the surgeon will ream a couple millimeters of bone and will have reached the reference point **710** (FIG. **7**) such that bone reaming is completed and the acetabular component **700** can be installed in the patient. In other instances, additional bone reaming is necessary to a depth depending upon the installation position **708** for a particular patient as determined during preoperative planning. When it is determined that additional bone reaming is necessary, in some instances the guide post **770** of FIG. **13**A remains installed in the patient and the second patient-specific jig **744** is utilized to determine if additional bone reaming is necessary; this is accomplished by inserting the second patient-specific jig **744** into the reamed acetabulum **705** over the guide post **770** and determining whether the three alignment member **746***a*, **746***b*, **746***c* are all in contact with selected areas **772***a*, **772***b*, **772***c* of the coxal bone **704**. If not, the surgeon may utilize the reaming machine **768** of FIG. **14** and ream additional bone material. The surgeon may continue to check the depth of the reamed acetabulum **705** by utilizing the second patient-specific jig **744** as noted above until all three alignment members **746***a*, **746***b*, **746***c* are in contact with the selected areas **772***a*, **772***b*, **772***c* of the coxal bone **704**. Once this is achieved, the surgeon will know with accurate precision that the reference point **710** has been reached and at the desired angle for accurate installation of the acetabular component **700** in the patient. The surgeon may then install the acetabular component **700** in the patient utilizing known techniques in the art. In the current method, a guide post may be utilized over which the acetabular component **700** may be more accurately placed than with standard techniques.

In other instances and where additional bone reaming is necessary but at a different angle than with respect to FIG. **14** according to preoperative planning, the guide post **770** is removed from the patient and a supplemental guide post **778** is installed in the patient to guide the reaming machine **768** at a different angle than the original guide post **770**. In some instances the supplemental guide post **778** may be removed prior to reaming and the sinus tract in bone may guide the surgeon to ream at an appropriate angle and to an appropriate depth. Such operative steps are determined by the surgeon, with the use of the computing system, during preoperative planning. For purposes of illustration and as one example, FIGS. **15**A and **15**B show the supplemental guide post **778** installed in the patient at a different angle than the guide post **770** of FIGS. **13**A and **14**. Accordingly, once the bone is reamed as described with reference to FIG. **14**, the guide post **770** is removed and the second patient-specific jig **744** is placed into the reamed acetabulum **705**. Similar to the first patient-specific jig **730**, the second patient-specific jig **744** is utilized to determine the orientation of the supplemental guide post **778** to be installed in the patient. Thus, the surgeon inserts the second patient-specific jig **744** into the reamed acetabulum **705** and rotates or otherwise orients the second patient-specific jig **744** in the patient until all three alignment members **746***a*, **746***b*, **746***c* are in contact with respective selected areas **772***a*, **772***b*, **772***c* of the coxal bone **704**, as depicted on FIGS. **15**A and **15**B. Once the second patient-specific jig **744** is properly oriented, the surgeon inserts the supplemental guide post **778** through the aperture **750** and the threads of the supplemental guide post **778** engage the bone. Thus, the supplemental guide post **778** will be installed at the exact position determined during preoperative planning and according to the installation position of the acetabular component **700**. The second patient-specific jig **778** may then be removed and a reaming machine **768** may be used to remove additional bone material from the patient, with or without the guide post in place.

FIG. **16** illustrates the reaming machine **768** used for such purpose. The reaming machine **768** includes a supplemental reaming head **780**, which may be a detachable head of a selected size corresponding to the size of the acetabular component **700** to be installed. The supplemental reaming head **780** may be smaller in size than the reaming head **774** of FIG. **14**, or it may be the same size. The supplemental reaming head **780** may include a guide aperture **782** that slidably receives the supplemental guide post **778**. The supplemental reaming head **780** reams bone with a consistent axial motion in a direction depicted by Arrow B because the guide aperture **782** includes a central axis coextensive with a central axis of the supplemental guide post **778** and because the guide aperture **782** closely receives the supplemental guide post **778**. Such reaming heads having a guide aperture are well known in the art and will not be described in greater detail.

FIGS. **17**A and **17**B show the third patient-specific jig **754** positioned in a reamed acetabulum **707** of the patient. These figures show a technique that incorporates the preoperative steps of FIGS. **1-4**A in that the third patient-specific jig **754** is a generated image that is superimposed over the generated image of the bone structure of a patient. These figures also show a technique that incorporates the operative steps practiced by a surgeon on a patient disclosed herein.

FIG. **17**A shows a reamed acetabulum **707** as the result of the surgeon reaming a portion of the acetabulum **705** to a desired depth, as discussed with reference to FIG. **16**. In some instances, the surgeon will ream one or two millimeters of bone and utilize the third patient-specific jig **754** to determine whether additional bone reaming is necessary before final installation of the acetabular component in the patient, as determined during preoperative planning. Thus, the surgeon inserts the third patient-specific jig **754** into the reamed acetabulum **707**. If all three alignment members **756***a*, **756***b*, **756***c* are in contact with respective selected areas **784***a*, **784***b*, **784***c* of the coxal bone **704**, then the third patient-specific jig **754** has indicated that the reference point **710** of the installation position **708** has been reached, and therefore, bone reaming is completed.

The surgeon will then install the acetabular component **700** according to known techniques or over a supplemental guide post using a cannulated acetabular impactor and mallet device as described herein. For purposes of discussion, FIG. **17**A shows that alignment member **756***b* is not in contact with the selected area **784***b* adjacent to the native acetabulum. As such, the illustrated third patient-specific jig **754** indicates that the reference point **710** has not been reached, and, therefore, additional bone reaming is necessary. Accordingly, the surgeon reams bone with the reaming head **780**, utilizing the supplemental guide post **778** pilot hole or sinus tract from the removed guide post as a guide member, and then inserts the third patient-specific jig **754** to determine whether all three alignment members **756***a*, **756***b*, **756***c* are in contact with the coxal bone **704** and the reference point **710** (FIG. **7**) has been reached by the supplemental reaming head **780**. These processes continue until the acetabulum is reamed to the desired depth of the reference point, at which point the surgeon installs the acetabular component **700** in the patient, as shown on FIG. **8**.

FIGS. **18**-**22** show aspects of the present disclosure in which an impactor tool **800** is used to assist with installation of an acetabular component **700** in a reamed acetabulum **705** or **707**. Typically, a reamed acetabulum is reamed to have a radius slightly smaller than the radius of the acetabular component for a tight fit configuration. As such, the surgeon typically utilizes a mallet or other tool to impact the acetabular component into its final position.

The impactor tool **800** includes a head **802** and a handle **804**. The head **802** includes a guide aperture **806** having a central axis X. During surgery and once the acetabulum is reamed to a desired depth, the acetabular component **700** is partially inserted into the reamed acetabulum. An elongated guide post **808** is installed in the coxal bone **704** and extends through a hole in the acetabular component **700**, as known in the art. A cannulated acetabular impactor device **810** includes a cannulated channel **812** that receives the elongated guide post **808**; the cannulated acetabular impactor device **810** may be threaded or slidably received over the elongated guide post **808**. The cannulated acetabular impactor device **810** includes a distal end **814** biased against the cup portion of the acetabular component **700**, and a proximal end **816** with a surface **818** to be impacted by the impactor tool **800**. The guide aperture **806** of the impactor tool **800** slidably receives a portion of the guide post **808**.

During installation of the actabular component **700**, the surgeon holds the handle **804** and slidably engages the guide aperture **806** of the impactor tool **800** with the guide post **808**. The surgeon then repeatedly impacts the surface **818** of the proximal end **816** of the cannulated acetabular impactor device **810** with the impactor tool **800**, causing an impacting force against the acetabular component **700**, until the acetabular component **700** is in its final position. Typically several impacts with the impactor tool **800** will suffice, and typically the surgeon can hear when the acetabular component **700** is seated flush against the acetabulum in its final position. One advantage of the impactor tool **800** is that impact against the elongated member **810** (and ultimately the acetabular component **700**) occurs at approximately the same impact location upon each repeated impact with the tool **800**. Typically, the surgeon uses a mallet or hammer without the assistance of any guidance, which can result in improper installation of the acetabular component **700**. The guide aperture **806** of the impactor tool **800** ensures repeatable impact location and position of the impactor tool **800**, which reduces or eliminates the possibility for human error during repeated impacts with a mallet or hammer.

The various embodiments described above can be combined to provide further embodiments. Aspects of the embodiments can be modified, if necessary to employ concepts of the various patents, applications and publications to provide yet further embodiments.

These and other changes can be made to the embodiments in light of the above-detailed description. In general, in the following claims, the terms used should not be construed to limit the claims to the specific embodiments disclosed in the specification and the claims, but should be construed to include all possible embodiments along with the full scope of equivalents to which such claims are entitled. Accordingly, the claims are not limited by the disclosure.

The invention claimed is:

1. A device for use in joint replacement surgery, the device comprising:

a patient-specific jig having a body formed using three dimensional data corresponding to a bone structure of a patient and a model of a reamed acetabulum, the body having a proximal end and a distal end and configured to be positioned against the bone structure of the patient at a joint location, the distal end of the body includes a reference surface that corresponds to a position and a shape of a surface of the model of the reamed acetabulum, the body including a first alignment member, a second alignment member, and a third alignment member, each alignment member positioned at respective locations adjacent the proximal end of the body and oriented corresponding to the three dimensional data of the bone structure, the alignment members configured to position and orient the body with respect to the bone structure to indicate to a surgeon that the position and the shape of the surface of a reamed acetabulum corresponds to a final installation position of a prosthesis implant to be secured to the bone structure of the patient according to the three dimensional data and the model of the reamed acetabulum.

2. The device of claim **1** wherein the body is configured to be positioned against an acetabulum, and further comprising an aperture formed through the body at an angle corresponding to an installation orientation of a reaming guide post based on the three dimensional data.

3. The device of claim **1** wherein the body is configured to be positioned against an acetabulum, and further comprising an aperture formed through the body at an angle corresponding to the installation position of the prosthesis based on the three dimensional data; and

wherein the reference surface of the body includes a position corresponding to a depth of the reamed acetabulum and an angular orientation of the final installation position of the prosthesis implant.

4. The device of claim **1** wherein each alignment member includes an engagement portion configured to engage a selected area adjacent the acetabulum of the patient to indicate information corresponding to the installation position of the prosthesis implant.

5. The device of claim **4** wherein each engagement portion of the alignment members is configured to contact one of a corresponding area adjacent a patient's medial rim, sciatic notch, and acetabular notch.

6. A system for use in joint replacement surgery, the system comprising:

a patient-specific device generator for generating a prosthesis implant image and a first patient-specific jig image, the prosthesis implant image superimposed over an image of the bone structure based on three dimensional data corresponding to a bone structure of a patient; and a patient-specific device converter for generating design control data to control operation of a machine configured to make a first patient-specific jig that corresponds to the generated first patient-specific jig image, the first patient-specific jig positionable against an unreamed bone structure of the patient at a position corresponding to the prosthesis implant image, the patient-specific device generator configured to generate a reamer guide post image at least partially superimposed through the image of the acetabulum, the reamer guide post image oriented according to preoperative surgery analysis to guide a reamer and in an orientation different than an orientation of the prosthesis implant image, the patient-specific device generator configured to generate an aperture through the first patient-specific jig image oriented corresponding to said reamer guide post image.

7. The system of claim **6** wherein the patient-specific device generator is configured to generate three alignment member images at positions on the first patient-specific jig image corresponding to selected areas adjacent the bone structure of the patient determined from the three dimensional data and the prosthesis implant image.

8. The system of claim **7** wherein the patient-specific device converter is configured to generate control data to control operation of the machine for making three alignment members attached to the first patient-specific jig.

9. The system of claim **7** wherein each of the three alignment members corresponds to one of three adjacent areas of a patient's specific bony anatomy adjacent an acetabulum.

10. The system of claim **6** wherein the patient-specific device generator is configured to generate three alignment member images on the first patient-specific jig image, each alignment member at a position corresponding the prosthesis implant image.

11. The system of claim **10** wherein the patient-specific device converter is configured to generate computerized control data for controlling the machine to form the first patient-specific jig having the three alignment members and the aperture based on respective images generated by the patient-specific device generator.

12. The system of claim **6** wherein the patient-specific device generator is configured to generate a second patient-specific jig image and to generate design control data to control operation of a machine for making the second patient-specific jig that corresponds to the generated second patient-specific jig image, the second patient-specific jig positionable against a reamed bone structure of the patient at a position corresponding to the prosthesis implant image.

13. The system of claim **12** wherein the patient-specific device converter is configured to generate control data to control operation of the machine for making three alignment members attached or attachable to the second patient-specific jig.

14. The system of claim **13** wherein each of the three alignment members is at a respective position on the second patient-specific jig in a location that corresponds to a selected area adjacent one of a medial rim, a sciatic notch, and an acetabular notch.

15. The system of claim **13** wherein the patient-specific device generator is configured to generate a prosthesis installation guide post image at least partially superimposed through the image of an acetabulum, the prosthesis installation guide post image oriented according to the prosthesis implant image, the patient-specific device generator further configured to generate an aperture through the second patient-specific jig image oriented corresponding to the prosthesis installation guide post image, the orientation of the aperture through second patient-specific jig image being different than the orientation of the aperture through the first patient-specific jig image.

16. The system of claim **12** wherein the patient-specific device generator is configured to generate a third patient-specific jig image and is configured to generate three alignment member images of the third patient-specific jig image at positions corresponding to selected areas adjacent the bone structure of the patient determined from the three dimensional data and the prosthesis implant image.

17. The system of claim **16** wherein the patient-specific device converter is configured to generate control data to control operation of the machine for making three alignment members attached to the third patient-specific jig, and wherein the patient-specific device converter is configured to generate design control data to control operation of a machine for making the second patient-specific jig that corresponds to the generated second patient-specific jig image.

18. The system of claim **17** wherein each of the three alignment members is at a respective position on the third patient-specific jig that correspond to a selected area adjacent one of a medial rim, a sciatic notch, and an acetabular notch or any three adjacent areas of a patient's specific bony anatomy adjacent an acetabulum.

19. The system of claim **16** wherein the patient-specific device generator is configured to generate a guide post image at least partially superimposed through the image of an acetabulum, the guide post image oriented according to the prosthesis implant image, the patient-specific device generator further configured to generate an aperture through the third patient-specific jig image oriented corresponding to said guide post image such that at least a portion of said guide post image extends through the aperture of the third patient-specific jig image.

20. The system of claim **6** wherein the patient-specific device generator is configured to generate a second patient-specific jig image and a third patient-specific jig image, each of the first, second, and third patient-specific jig images having three alignment members and an aperture.

21. The system of claim **20** wherein the patient-specific device converter is configured to generate design control data to control operation of a machine for making the first, second, and third patient-specific jigs that correspond to the respective generated images, each set of the three alignment members of each patient-specific jig positionable in the acetabulum to indicate information pertaining to an installation position of a prosthesis implant based on the prosthesis implant image.

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